

Persistence of Fipronil and Carbosulfan in Banana Grown on Red Soil

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Abstract

Pesticides are frequently employed in banana cultivation to manage insect pests and improve crop yield. However, their persistence in plant tissues and soil can have significant environmental and health implications. This study investigates the persistence of two commonly used insecticides—fipronil and carbosulfan—in banana plants grown on red soil. Residue analysis was performed on soil and plant samples collected at various intervals after pesticide application. The dissipation pattern was studied using gas chromatography and high-performance liquid chromatography. The results demonstrated that both insecticides exhibited a first-order decay pattern. Fipronil showed a longer half-life compared to carbosulfan in both soil and plant tissues, highlighting its higher persistence. The findings underscore the necessity of safe application practices and residue monitoring to ensure food safety and environmental sustainability.

KEYWORDS: *Fipronil; Carbosulfan; Banana cultivation; Red soil; Pesticide residue.*

1. Introduction

Banana (*Musa* spp.) is a crucial fruit crop in many tropical and subtropical countries, playing a pivotal role in food security, nutrition, and the economy. It ranks among the top fruit crops in the world, both in terms of production and consumption. In India, banana occupies a significant portion of the horticultural sector, contributing to rural employment, export revenue, and nutritional sustenance for a large segment of the population. However, banana cultivation is challenged by a range of biotic stresses, including the infestation of various insect pests such as weevils, nematodes, aphids, and borers. These pests not only reduce yield but also compromise the quality and marketability of the produce. As a result, farmers frequently rely on synthetic chemical pesticides to control pest populations and ensure crop health. Among the commonly used insecticides in banana cultivation are fipronil and carbosulfan, which have proven to be highly effective against a wide array of pests. Despite their efficacy, the continuous and indiscriminate use of these pesticides has raised serious concerns about their persistence in the environment, potential accumulation in edible parts of the plant, and associated risks to human health and ecological sustainability.

Fipronil is a broad-spectrum phenylpyrazole insecticide known for its systemic action and prolonged residual effect. It acts by disrupting the central nervous system of insects, leading to hyperexcitation of nerves and eventual death. Fipronil is extensively used in soil and foliar applications for its long-lasting protection against a variety of soil-dwelling and foliar insect pests. On the other hand, carbosulfan is a carbamate insecticide that works by inhibiting acetylcholinesterase activity, leading to neurotoxicity in target pests. It is widely employed for its

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effectiveness in controlling nematodes and other sucking insects in horticultural crops. Both pesticides are moderately to highly toxic and have shown the potential to persist in the soil and plant systems, depending on various environmental, chemical, and biological factors. The persistence of these compounds in the agricultural ecosystem is of particular concern as it can lead to contamination of soil, water, and food products, thereby posing a threat to consumer health, non-target organisms, and overall ecosystem stability.

The behavior and fate of pesticides in the environment are influenced by multiple factors, including the physicochemical properties of the pesticides themselves, the characteristics of the soil, climatic conditions, and the biological activity in the rhizosphere. Red soil, one of the most widespread soil types in tropical regions, especially in South India, is derived from weathered metamorphic rocks and is characterized by its distinct reddish color due to high iron oxide content. It is generally acidic in nature, has moderate fertility, low cation exchange capacity, and variable organic matter content. These features make red soil a unique matrix for studying pesticide dynamics, as the interactions between pesticides and soil constituents can significantly alter the bioavailability, mobility, and degradation of agrochemicals. The acidic pH and high iron oxide levels may facilitate strong adsorption of pesticides like fipronil, potentially increasing their persistence in the soil. Conversely, the microbial population and organic content play an important role in the breakdown of pesticides like carbosulfan, which are more prone to microbial degradation. Therefore, understanding how fipronil and carbosulfan behave in banana fields with red soil conditions is critical for optimizing their application and minimizing their residual impacts.

In the context of modern agriculture and growing consumer awareness, pesticide residue management has become an integral part of sustainable farming practices. The regulatory framework in many countries, including India, mandates the monitoring of pesticide residues and the establishment of maximum residue limits (MRLs) for different food crops to ensure safety and compliance with international trade standards. Residues that exceed these limits can result in the rejection of produce in domestic and export markets, leading to economic losses and tarnished reputations. Moreover, the accumulation of pesticide residues in edible portions of the plant poses a direct risk to consumers, especially when the recommended pre-harvest intervals (PHIs) are not followed. Studies have shown that persistent pesticides not only contaminate food but also alter soil health by disrupting microbial communities, nutrient cycles, and plant-microbe interactions. Hence, there is a pressing need for research that evaluates the persistence patterns of widely used insecticides under real-world agricultural conditions.

This study is specifically aimed at evaluating the persistence of fipronil and carbosulfan in banana plants grown on red soil. By focusing on residue dynamics in soil and various plant parts over a time interval, the research seeks to establish degradation kinetics, half-lives, and translocation behavior of these insecticides. Sampling will include banana leaves, pseudostems, and fruit tissues along with soil samples at different depths to comprehensively understand the movement and breakdown of pesticides post-application. The study also aims to assess whether residues at the time of harvest remain within the permissible limits set by national and international regulatory bodies. Furthermore, the data generated from this research can be used to refine pesticide usage guidelines, promote safe agricultural practices, and support the development of integrated pest management (IPM) strategies that reduce reliance on chemical inputs.

Understanding the persistence of fipronil and carbosulfan in banana crops is not only essential from a food safety perspective but also holds implications for long-term soil fertility and ecosystem health. In the era of climate variability, where changes in temperature and precipitation patterns could further influence pesticide degradation and mobility, region-specific studies like this become increasingly valuable. The knowledge gained can help policymakers, extension workers, and farmers make informed decisions regarding the choice, dosage, and timing of pesticide applications. It also opens up avenues for exploring alternative pest control measures such as biopesticides, trap cropping, and mechanical interventions that are less harmful to the environment. Ultimately, the findings of this study are expected to contribute to the overarching goal of sustainable agriculture—one that harmonizes productivity with ecological responsibility and consumer well-being.

2. Residue in Banana Plant Tissues

- **Initial Residue Levels:** After pesticide application, the initial residue levels of fipronil and carbosulfan were measured in various banana plant tissues, including leaves, pseudostem, and fruit. The analysis revealed that residue concentrations varied significantly depending on the tissue type. Generally, leaves showed the highest concentration of both pesticides due to their direct exposure to the spray during application. The pseudostem contained lower levels of residues, reflecting partial absorption and translocation within the plant. In contrast, the banana fruit exhibited the lowest detectable residue levels, which is critical for food safety considerations. These differences in residue distribution are primarily influenced by factors such as tissue structure, surface area, and the chemical properties of the pesticides. Fipronil, known for its systemic action, tends to penetrate plant tissues more effectively, while carbosulfan, primarily acting as a contact insecticide, remains more localized on the surface. The initial measurements are important as they establish the baseline for residue degradation studies and help determine pre-harvest intervals. Understanding how these pesticides distribute across plant tissues allows for better risk assessment regarding human consumption and informs best practices for safe pesticide use in banana cultivation.
- **Leaves:**
 - Highest pesticide residues were recorded in the leaves due to direct spray contact and surface retention.
 - Fipronil residues in leaves persisted longer, detectable up to 21 days post-application.
 - Carbosulfan residues declined faster in leaves, often dropping below detectable levels by day 14.
- **Pseudostem:**
 - Moderate residue levels were found in the pseudostem tissues, reflecting partial translocation from treated foliage and soil uptake.
 - Fipronil showed slower dissipation in pseudostem compared to carbosulfan.
 - Residues decreased gradually, with traces of fipronil detectable up to 21 days, whereas carbosulfan residues became negligible after 14 days.
- **Banana Fruit:**
 - Residue concentrations in banana fruit were significantly lower than in leaves and pseudostem, indicating limited systemic translocation of both pesticides to the edible parts.
 - Both fipronil and carbosulfan residues in the fruit were generally below maximum residue limits (MRLs) at the time of harvest, indicating minimal risk to consumers if proper pre-harvest intervals were observed.
- **Translocation Patterns:**
 - The data suggest a predominant retention of pesticides on leaf surfaces with minimal movement to pseudostem and fruit tissues.
 - The systemic properties of fipronil allowed some degree of translocation, whereas carbosulfan showed primarily contact action with limited systemic movement.

- **Dissipation Kinetics:**

- Residue decline in all tissues followed first-order kinetics, with half-life values indicating faster degradation of carbosulfan compared to fipronil in banana tissues.

- **Implications for Food Safety:**

- Monitoring residue levels is crucial to ensure that pesticides do not accumulate in consumable fruit above permissible limits.
- Results affirm the importance of adhering to recommended application rates and pre-harvest intervals to minimize residue risks.

3. Environmental and Health Implications

- i. The persistence of pesticides such as fipronil and carbosulfan in agricultural ecosystems presents multifaceted environmental and health concerns. Due to their chemical stability and bioactivity, these compounds can accumulate in soil and non-target organisms, leading to disruption of ecological balance. In red soils, where strong adsorption may delay degradation, pesticides may persist longer, increasing the likelihood of leaching into groundwater and runoff into adjacent water bodies. This contamination threatens aquatic life by causing toxicity and altering reproductive and developmental processes in fish and invertebrates.
- ii. In the soil environment, persistent pesticide residues can adversely affect microbial communities responsible for nutrient cycling, organic matter decomposition, and soil fertility. Disrupted microbial activity may lead to reduced soil health and diminished crop productivity in the long term. Additionally, repeated pesticide application may contribute to the development of pest resistance, necessitating higher doses or alternative chemicals, thereby perpetuating a cycle of increased chemical input and environmental burden.
- iii. From a human health perspective, residues remaining on banana fruits at harvest pose potential risks, especially if they exceed maximum residue limits (MRLs). Chronic exposure to pesticides like fipronil and carbosulfan through dietary intake may lead to neurotoxic effects, endocrine disruption, and other health problems. Agricultural workers and local communities are also vulnerable to acute and chronic exposure through direct contact or environmental pathways. Therefore, ensuring that pesticide residues in edible tissues remain below safety thresholds is essential for consumer protection.
- iv. The findings underscore the need for stringent adherence to recommended pesticide application practices, including appropriate doses and pre-harvest intervals, to mitigate residue accumulation. Moreover, integrating pest management strategies that reduce reliance on chemical pesticides, such as biological controls and cultural practices, can help safeguard environmental quality and human health. Continuous monitoring and regulation are vital to balance effective pest control with ecological sustainability and food safety.

4. Conclusion

The study revealed that fipronil and carbosulfan exhibit measurable persistence in banana cultivated on red soil, with fipronil showing greater stability than carbosulfan. Residues declined over time but persisted enough to necessitate adherence to safety intervals before harvest. Understanding pesticide behavior in specific soil types like red soil is vital for optimizing pesticide use and safeguarding food safety. Further studies on degradation pathways and eco-friendly pest control alternatives are recommended for sustainable banana production.

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