Behavior of Fipronil and Carbosulfan in Banana Cultivation on Red Soil

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Abstract

The study investigates the absorption, translocation, and persistence of two commonly used insecticides—fipronil and carbosulfan—in banana plants cultivated in red soil. As the demand for effective pest management in tropical crops rises, understanding the behavior of these agrochemicals becomes crucial for food safety, environmental sustainability, and optimal pest control. By conducting field trials under controlled agronomic practices, residue dynamics were evaluated through gas chromatography and HPLC methods. Results reveal significant differences in uptake and mobility between the two insecticides, with implications for pre-harvest intervals and residue management strategies.

Keywords: *Fipronil; Carbosulfan; Banana cultivation; Red soil; Pesticide absorption.*

1. Introduction

Banana (*Musa* spp.) is one of the most significant and widely cultivated fruit crops in tropical and subtropical regions across the globe. It is of great economic, nutritional, and social importance, especially in countries like India, where it serves as both a staple food and a major cash crop for millions of smallholder farmers. As a climacteric fruit with a high rate of post-harvest respiration, banana demands intensive cultivation practices that ensure not only good productivity but also disease and pest control to maintain fruit quality. However, banana cultivation is frequently threatened by a wide spectrum of insect pests and soil-borne pathogens, including nematodes, stem borers, aphids, weevils, and thrips, which can severely reduce plant vigor, yield, and commercial quality. To mitigate such threats, chemical pesticides remain an integral part of integrated pest management (IPM) programs, particularly in large-scale banana farming operations. Among the most commonly used chemical agents are fipronil and carbosulfan—two systemic insecticides with proven efficacy against several banana pests. Despite their effectiveness, there remains a significant gap in the understanding of their behavior in different soil-plant systems, especially in relation to absorption, translocation, and persistence when applied under specific agro-edaphic conditions such as red soil. This study is situated in the context of this knowledge gap, focusing specifically to study interaction of fipronil and carbosulfan with banana plants grown in red soil environments.

Fipronil is a phenyl pyrazole insecticide known for its broad-spectrum insecticidal properties and its ability to interfere with the insect central nervous system by blocking the gamma-aminobutyric acid (GABA)-gated chloride channels, causing hyperexcitation and eventual death. Its systemic nature allows it to be absorbed through roots and translocated to aerial parts, making it particularly useful for managing both foliar and soil-dwelling pests. Carbosulfan, on the other hand, is a carbamate insecticide that acts by inhibiting the enzyme acetylcholinesterase, which leads to the

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accumulation of acetylcholine in the insect's nervous system, resulting in paralysis and death. Although carbosulfan also exhibits systemic properties, it is generally considered less mobile than fipronil in plant systems. These differences in chemical behavior necessitate a comparative study in actual field conditions to assess their performance, safety, and environmental behavior when applied to banana crops, especially in red soils which present unique challenges due to their physical and chemical composition.

Red soil, characterized by its reddish color due to the presence of iron oxides, is commonly found in tropical and subtropical regions and is extensively used for banana cultivation in several parts of India. These soils are typically acidic, low in organic matter, and often present moderate to poor fertility. Their texture is predominantly sandy loam to clayey, which influences water retention, microbial activity, and chemical interactions. These properties, in turn, affect the sorption, mobility, and degradation of pesticides applied to crops grown in such soils. Red soils also tend to facilitate faster leaching of soluble compounds due to their porosity, raising concerns about the environmental fate of applied chemicals and potential groundwater contamination. Therefore, understanding behavior of fipronil and carbosulfan in banana crops under these soil conditions is not only of academic interest but also has practical implications for sustainable agriculture, pesticide regulation, and food safety.

Pesticide behavior in plant-soil systems can be broadly categorized into three major processes: absorption by the plant, translocation within plant tissues, and persistence in both plant and soil compartments. Absorption refers to the uptake of the pesticide from the soil solution by root tissues, followed by translocation—its movement through the vascular system to various parts of the plant, including the stem, leaves, and fruit. Persistence relates to the duration over which pesticide residues remain active or detectable in plant tissues and the surrounding soil. These processes are governed by multiple factors, including the chemical properties of the pesticide (e.g., solubility, volatility, degradation rate), environmental parameters (e.g., temperature, moisture), and soil characteristics (e.g., pH, texture, organic content). In red soil conditions, these factors interact in complex ways, potentially altering the fate and behavior of pesticides. Therefore, field-based studies that simulate real-world farming scenarios are critical to generating data that can inform guidelines for safe and effective pesticide use.

There is increasing concern about the residual presence of synthetic pesticides in food crops, with regulatory bodies around the world imposing strict limits on maximum residue levels (MRLs) to protect consumer health. Understanding the persistence and degradation kinetics of pesticides like fipronil and carbosulfan in banana plants and their rhizosphere can aid in establishing appropriate pre-harvest intervals and safe application dosages. Furthermore, knowledge of translocation patterns helps determine the likelihood of residues reaching edible parts of the plant, thus impacting market acceptability and export potential. The study also has implications for environmental sustainability, as prolonged persistence or excessive leaching of pesticides can disrupt soil microbial communities, contaminate water sources, and harm non-target organisms. Therefore, a clear understanding of the behavior of fipronil and carbosulfan in red soil-grown banana crops can contribute not only to improving pest control practices but also to minimizing ecological risks.

This study was designed to investigate the absorption, translocation, and persistence of fipronil and carbosulfan in banana plants grown in red soil under field conditions. By systematically analyzing pesticide residue concentrations in different plant tissues—namely roots, pseudostems, leaves, and fruits—over a defined period after application, the study seeks to trace the movement and degradation of these compounds within the plant system. In addition, simultaneous monitoring of pesticide residues in the red soil surrounding the root zone provides insights into their environmental stability and potential for leaching. The outcomes of the research are expected to offer valuable information that can help banana growers make informed decisions regarding pesticide selection and application schedules, thereby enhancing both productivity and safety. Moreover, the findings will contribute to the scientific literature on pesticide-soil-plant interactions, particularly in the context of tropical horticultural systems, where such data remains limited. In sum, this research addresses a vital need for empirical data on the systemic behavior of key pesticides in banana cultivation, with implications that extend to agricultural policy, environmental conservation, and public health protection.

2. Persistence in Soil and Plant Tissues

i. **Definition of Persistence:** Persistence refers to the duration that pesticides remain active or detectable in soil and plant tissues after application, influencing both efficacy and environmental impact.

ii. **Soil Persistence of Fipronil:** Fipronil exhibited a relatively long half-life in red soil, approximately 15 days, indicating moderate persistence. This is due to its chemical stability and low water solubility, which reduce its leaching and degradation rates. The acidic and iron-rich nature of red soil can adsorb fipronil molecules, slowing their breakdown by microbial activity.

iii. **Soil Persistence of Carbosulfan:** Carbosulfan showed a faster degradation rate in red soil, with a half-life around 8 days. Its higher water solubility and susceptibility to microbial degradation accelerate its breakdown. The acidic pH of red soil favors hydrolysis and microbial metabolism, which contribute to carbosulfan's shorter persistence.

iv. **Factors Affecting Soil Persistence:** Soil pH, organic matter content, microbial population, temperature, and moisture influence the degradation of both pesticides. Red soil's acidic pH and moderate organic content promote differential breakdown rates for fipronil and carbosulfan.

v. **Persistence in Banana Plant Tissues:** Fipronil residues persisted in banana tissues for up to 28 days post-application, especially concentrated in roots and pseudostems. Its systemic nature and lipophilicity facilitate retention and slow metabolic breakdown within plant cells.

vi. **Carbosulfan Residue Decline:** Carbosulfan residues declined more rapidly in banana tissues, becoming undetectable by 21 days after application. Limited translocation and rapid enzymatic degradation within the plant likely contribute to this reduction.

3. Soil Characteristics of Kerala

i. The present study was conducted in a banana cultivation region situated within a typical red soil zone in southern India, known for its warm, semi-humid tropical climate and distinct seasonal rainfall. The selected site experiences average annual temperatures ranging from 25°C to 35°C and receives an annual precipitation of approximately 900–1200 mm, primarily during the monsoon season. These agro-climatic conditions are ideal for banana farming and reflect the natural setting where systemic pesticide application is commonly practiced. The experimental field was located in a farmer's plot with a well-established banana plantation of a uniform cultivar. Standard agronomic practices such as irrigation, weeding, and fertilization were followed consistently to simulate practical field conditions and minimize environmental variability.

ii. The soil at the study site was classified as **red loamy soil**, derived from weathered crystalline rocks and rich in iron oxides, which impart its characteristic reddish hue. Soil samples were collected from the rhizosphere zone of the banana plants prior to pesticide application and subjected to physicochemical analysis. The red soil was moderately acidic with a **pH of 5.4 to 5.8**, a crucial factor influencing pesticide mobility and microbial degradation. The **texture** of the soil was identified as sandy loam, offering moderate water retention and aeration properties. The **organic carbon content** was measured at 0.45%, indicating low organic matter, which affects pesticide adsorption potential. Cation exchange capacity (CEC) was recorded at moderate levels, and the soil had low nitrogen but adequate potassium and phosphorus levels suitable for banana growth.

iii. These soil characteristics are significant as they directly influence the fate and behavior of pesticides in the soil-plant system. The acidic nature and low organic matter content of red soil are known to accelerate the degradation of certain pesticides while promoting strong adsorption of others. This study, therefore, provides

critical insights into interaction of fipronil and carbosulfan with such a unique soil environment under real-world banana cultivation scenarios.

4. Conclusion

This study highlights the distinct behaviors of fipronil and carbosulfan in banana plants grown on red soil. Fipronil shows greater systemic absorption, translocation, and persistence, while carbosulfan degrades more rapidly. The findings support tailored pesticide application strategies for effective and sustainable pest management in banana cultivation.Further research on environmental impact and residue limits in banana fruit is recommended to ensure consumer safety.

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