Evaluation of the Persistence of Concentrated Mancozeb Suspensions on Foliar Tissue with Variable Moisture: Impact of Surface Tension

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■ ABSTRACT

The effect of foliar wettability on the coverage and adhesion of various mixtures of systemic and protective fungicides based on mancozeb was evaluated. The product was applied using a "wet leaf" methodology, simulating spraying under conditions of high relative humidity or dew presence, where the pre-existing water film usually compromises adhesion to banana plant leaves (genus Musa). The results demonstrate that the 62% mancozeb suspension concentrate formulation achieved retention levels of 92%, greatly surpassing standard mixtures based on wettable powders or conventional emulsifiable concentrates. The data confirm that the product possesses superior mechanical fixation capacity due to the micrometric nature of the suspension, which optimizes adsorption capacity. This study also supports redefining field application methodologies for mancozeb suspensions, prioritizing dry application conditions, partial environmental humidity, and low precipitation.

■ INTRODUCTION

In commercial agrochemical applications, the condition of the foliar tissue is a determining factor in treatment efficacy. Persistence represents the resistance of the phytosanitary deposit to removal by external agents (rain, wind) from the foliar tissue, whereas adhesion is the molecular attraction between the product and the surface. This phenomenon reflects the interaction between the solid and liquid phases described in colloid chemistry; fungicide efficacy depends on its ability to establish an exchange complex or "adsorption" on the waxy cuticle. Fungicide stability on the leaf is determined by Van der Waals forces, interactions that determine material cohesion. At the cuticle-fungicide interface, these forces, together with hydrogen bonds, are responsible for agrochemical persistence. The formulation must act at the interface through electrostatic forces that stabilize the deposit against surface leaching. The research focused on determining how nighttime or morning humidity affects the retention of mancozeb-based fungicidal suspension concentrates when combined with different systemic agents and oils.

■ EXPERIMENTAL

A triplicate study was conducted using 3 samples of mancozeb-based suspension concentrates (manganese and zinc ethylene bis-dithiocarbamate; $C8H12MnN4S8Zn$) and three different systemic fungicidal agents. The tests were performed in plantations located in the northern Caribbean sub-watershed of Río Frío, Costa Rica. Applications were carried out using a ground-based CO_2 system with a total spray volume of 18 L/ha. Leaves were evaluated under three conditions: wet (natural dew), semi-wet, and dry.

The following generic mixtures were used:

Mixture A: Epoxiconazole-based fungicidal emulsifiable concentrate at 7.5% w/v + mancozeb suspension concentrate + mineral oil.

Mixture B: Triazole-based fungicidal emulsifiable concentrate at 25% w/v + mancozeb suspension concentrate + mineral oil.

Mixture C: Fenpropimorph-based fungicidal oil solution at 88% w/v + mancozeb suspension concentrate + mineral oil.

Each mixture was applied to 2 Musa leaves under wet conditions (natural dew), 2 dry leaves (artificial drying), and 2 leaves under semi-wet conditions (light shaking).

■ RESULTS DISCUSSION

It was observed that, regarding wettability, mancozeb suspension concentrates exhibit runoff toward leaf inclination points (edges, tips, and bases) on wet and dew-covered leaves (see Figure 1).

Figure 1. Musa leaf with dew (natural moisture) and applied product.

This behavior results from the disruption of the surface tension of pre-existing water droplets, which drag part of the applied mixture, reducing product persistence. The foliar structure of Musa plants is characterized by a hydrophobic cuticle that imposes a severe electrostatic barrier to any aqueous or highly polar solution. When the leaf is wet, H_2O molecules occupy intermolecular attraction sites on the carboxyl and phenolic groups present in the cuticle, preventing mancozeb and other systemic fungicides such as triazoles from establishing efficient attractions with the stomata that make up the leaf surface. In contrast, on a dry leaf, organic adsorbents are available to interact directly with the particles of the suspension concentrate (SC). Surfactants effectively reduce surface tension, allowing Van der Waals forces to fix the product without interference from the water layer, thereby eliminating this runoff phenomenon toward the leaf base. The epicuticular waxes of banana leaves are inherently hydrophobic; application success depends on the fungicide's ability to establish Van der Waals forces, which are relatively weak molecular bonds.

Another phenomenon that explains product runoff is the balance of divalent cations present

in the Musa leaf cuticle. The electrochemical balance influences the adsorption potential of surface matter. A deficiency or imbalance of divalent cations such as Ca^{2+} and Mg^{2+} can reduce the stability of the cationic bridges required for the adsorption of polymers and organic particles present in the formulation, exacerbating runoff risk under foliar water stress. Under dew or high humidity conditions, the dilution of divalent cations in water may increase the surface tension of the product and consequently form more spherical, higher-volume droplets that accumulate together and are easily displaced off the leaf.

Figure 2. Musa leaf under dry conditions with applied product.

As shown in Figure 2, applications performed on dry foliar tissue exhibit optimal adhesion and persistence, since no mechanical dragging or displacement of the product toward the natural drainage zones of the leaf blade (edges, apex, and base) occurs. This behavior highlights the importance of the application window and the integrity of the lipoid cuticle, which in Musa plants is characterized by significant thickness and the presence of epicuticular waxes that confer marked hydrophobicity and impermeability.

■ CONCLUSION AND RECOMMENDATION

The persistence of mancozeb suspension concentrates is inversely proportional to the degree of moisture present in the tissue at the time of application. Applications on dry tissue or under partial humidity conditions should be prioritized to avoid active ingredient loss due to runoff, a critical factor that must be considered to optimize both aerial and ground application windows.

■ REFERENCES

(1) Navarro Blaya, S.; Navarro García, G. Agricultural Chemistry: Soil and Essential Chemical Elements for Plant Life, 2nd ed.; Ediciones Mundi-Prensa: Madrid, 2003; pp. 233–247, 321–336.

(2) Carbonero Zalduegui, P. Soil and Fertilizer Chemistry; Chapter 1: The Plant, Soil and Fertilizers; Chapter 2: Soil as an Ion Exchanger; Monographs of the Higher Technical School of Agricultural Engineers, Polytechnic University of Madrid: Madrid, 1975; pp. 10–15, 26–30, 37–38.

(3) Skutch, A.F. 1932. Anatomy of the Axis of the Banana. Botanical Gazette 93(3):233–258.

(4) IPGRI-INIBAP and CIRAD. 1996. Descriptors for banana (Musa spp.). IPGRI, Rome, Italy. 55 p.

(5) Kirchoff, B.K. 1992. Ovary Structure and Anatomy in the Heliconiaceae and Musaceae (Zingiberales). Canadian Journal of Botany, 70(12):2490–2508.