Comparison of electrostatic and coldfog sprayers using cold field emission scanning electron microscopy and energy dispersive x-ray microanalysis.

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Abstract

Handgun-type electrostatic and high-pressure coldfog sprayers were evaluated in a production greenhouse. Spray distribution and canopy penetration were evaluated using cold field emission scanning electron microscopy (CFESEM) with energy dispersive x-ray analysis. When both instruments are used together, the technique is termed as cold field emission electron beam analysis (CFE-EBA). This unique, alternative imaging assessment method improved clarity and resolution resulting in higher magnification of fungicide/tracer residue, not previously available with conventional thermionic scanning electron microscopes. The use of CFESEM minimized specimen preparation time by eliminating the need for coating and other histological procedures. CFE-EBA indicated that the electrostatic sprayer used in this study demonstrated superior coverage over that of the coldfog sprayer.

Introduction

Greenhouse and floricultural crops in the United States represent more than $5 billion (U.S.) per annum in farmgate receipts. Plant diseases consistently reduce the value of these crops and increase production costs through routine fungicide applications. Precise fungicide placement on target crop surfaces is critical to minimize fungicide use. Electron beam analysis (EBA) is a unique alternative assessment method to conventional methods. EBA combines conventional scanning electron microscopy (SEM) and energy dispersive x-ray analysis (EDXA) with digital image analysis. Recently, a new tool, a cold field emission scanning electron microscope (CFESEM), was combined with EDXA to assess the uniformity of fungicide coverage within a greenhouse canopy. Fungicide was applied with either a handgun-type electrostatic sprayer or a handgun-type coldfog sprayer.

Materials and Methods

Plant material: Rooted cuttings of 2-month-old *Fuchsia* spp. were randomly placed throughout a commercial greenhouse within the canopy of other bedding plants. *Fuchsia* plants were removed for study following each spray treatment. Leaf samples were taken from 10 cm and 5 cm above the potting mix surface to assess canopy penetration. A specimen holder served as an inert target at the base of the plant. Fresh, untreated plants were replaced before the next treatment.

Treatments: Treatments were applied using either an Electrostatic Spraying Systems Co. (ESS), handgun-type, air-atomizing, induction charging, electrostatic sprayer (Model no. EPS 5) or a handgun-type, high pressure, Dramm Coldfog sprayer (Dramm Model #K601-RW). The ESS sprayer applied approximately 9 L of spray to the greenhouse and the Dramm Coldfog applied approximately 20 L. The treatments consisted of the fungicide, copper sulfate pentahydrate (Phyton-27, Source Technology Biologicals, Inc.) and a fluorescent tracer, Tinopal CBS-X (Keystone).

Electrostatic Spraying System

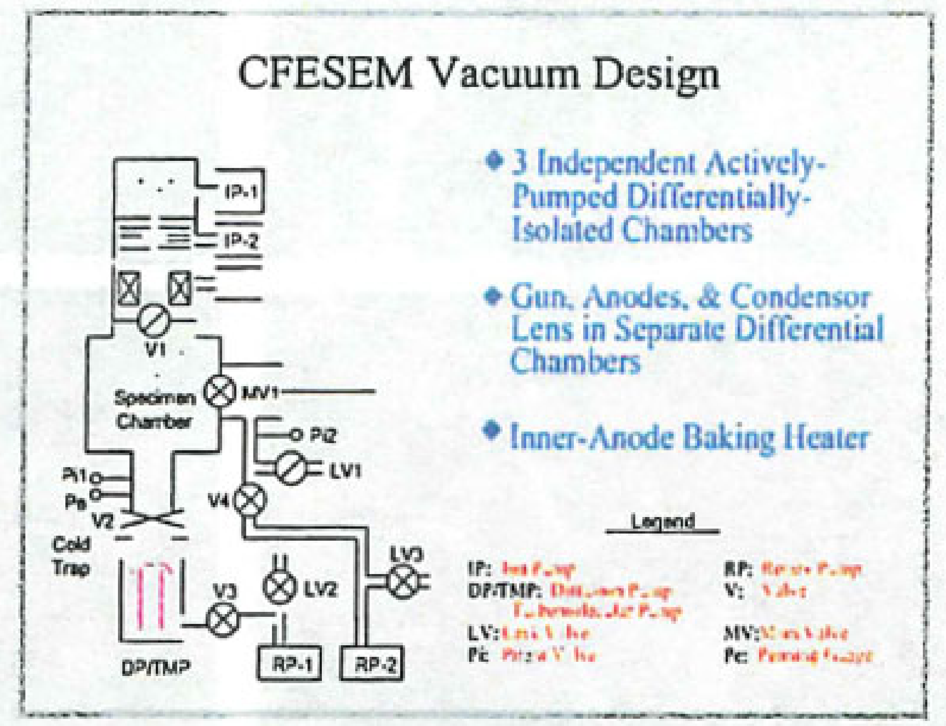
Dramm Coldfog Sprayer

Cold Field Emission - Electron Beam Analysis

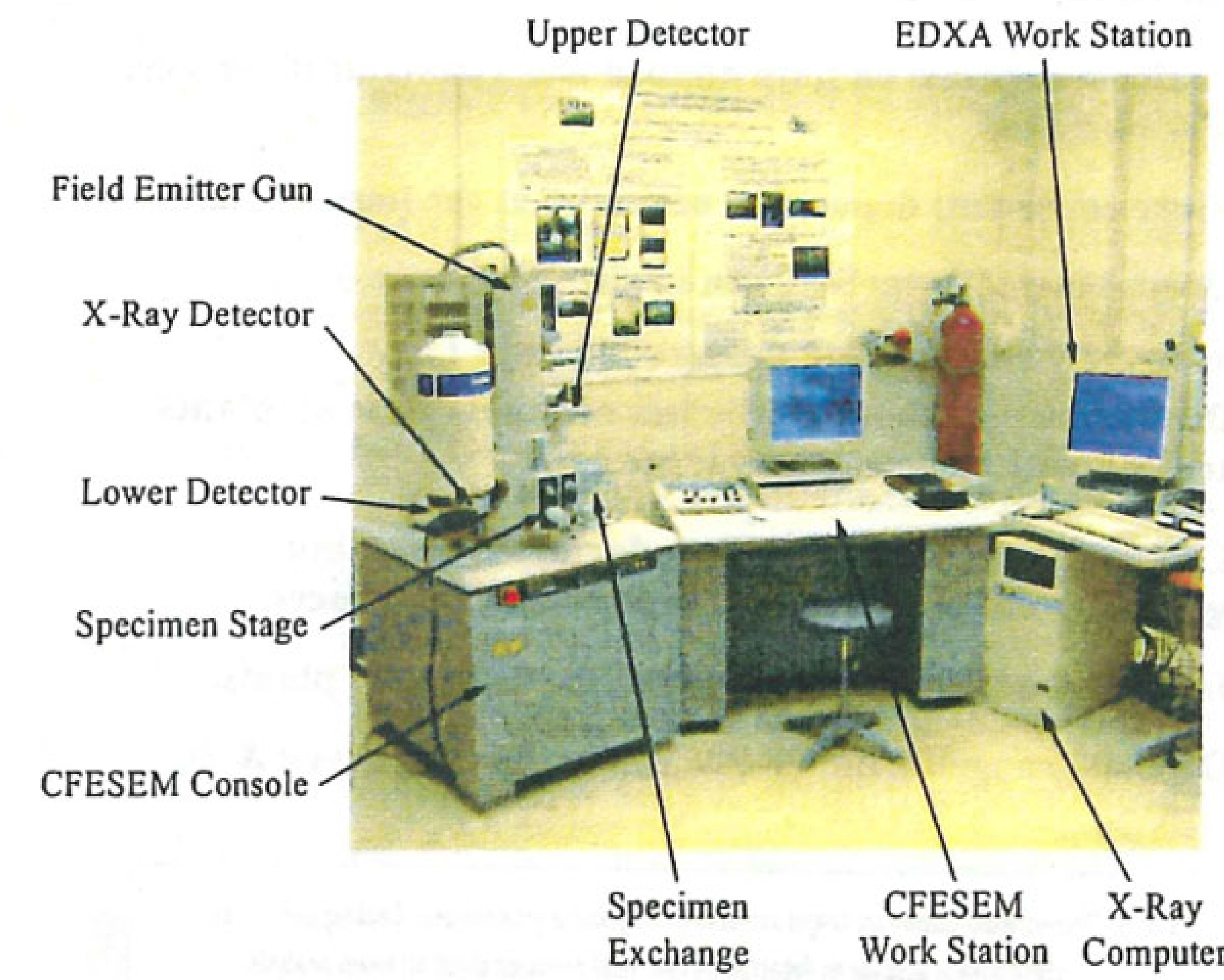
CFESEM & EDXA:

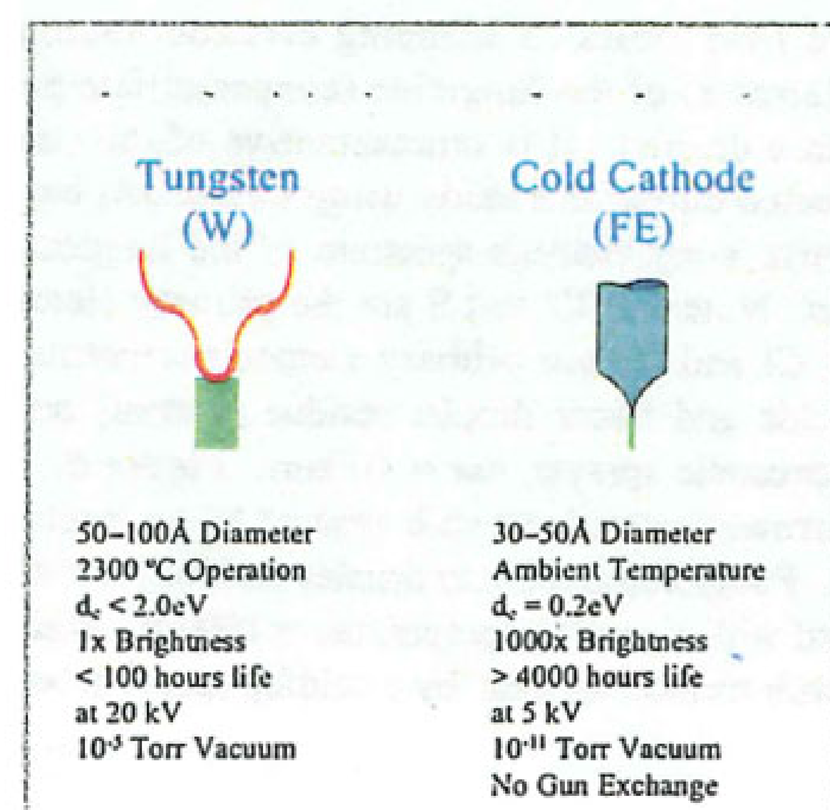
Samples were mounted on stubs, and examined in the Hitachi Model S4700 CFESEM set at 15 mm working distance, acceleration voltage of 5 kV and beam current of 10 μamps. EDXA was performed using a Voyager III (Noran, Inc., Middleton, WI). Coverage was recorded on the basis of the average of 3 observations/sample, examined at x350. The size of the area of each observation was approximately 200 x 300 μm.

CFESEM + EDXA = CFE-EBA

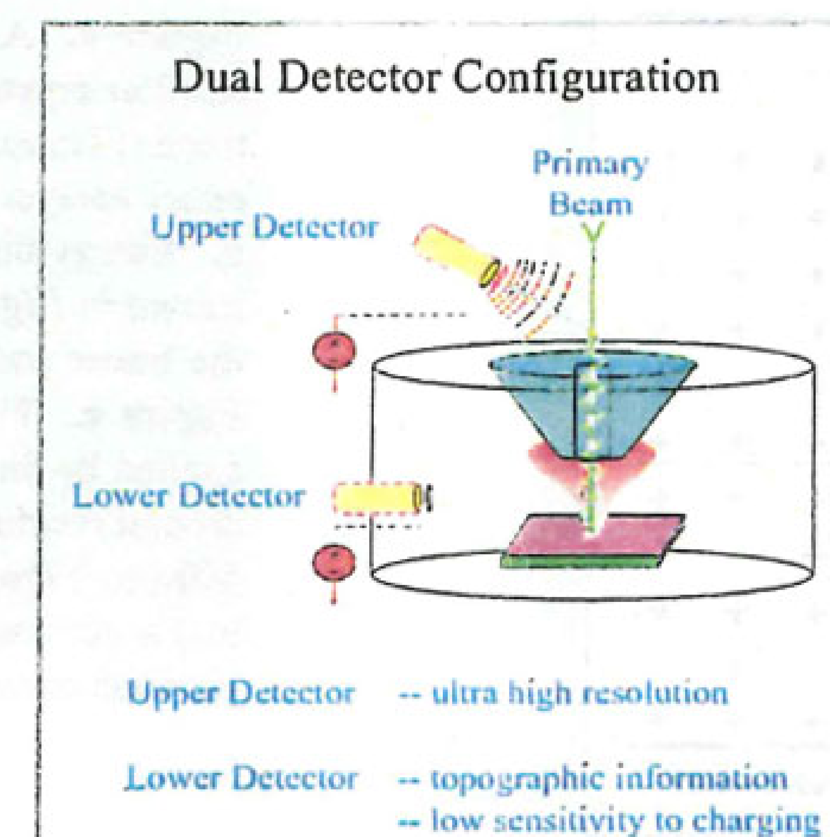


Generation of the beam with ultra high vacuum.

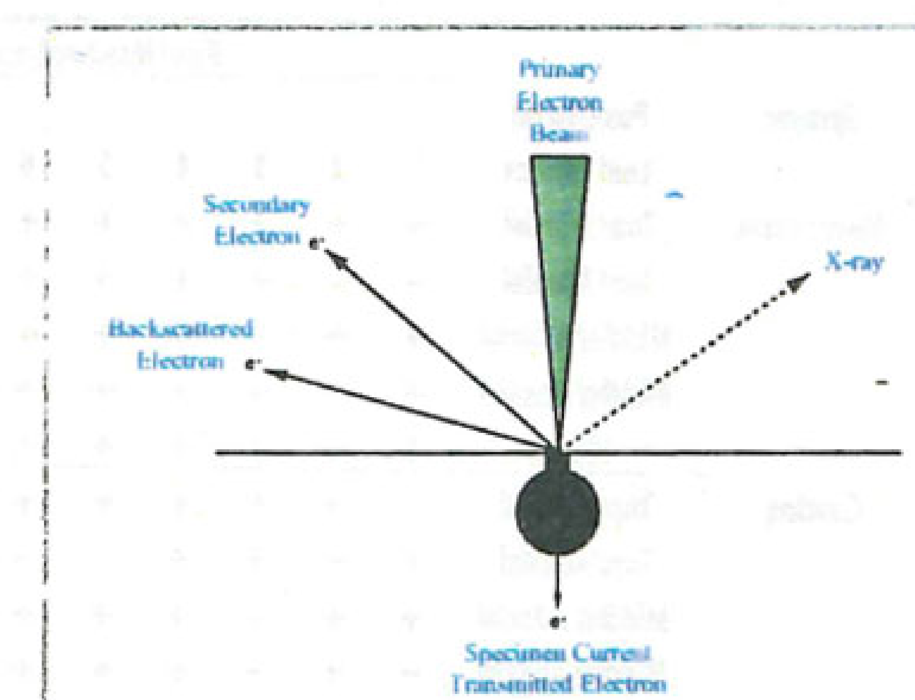




At 5 kV acceleration voltage, the cool fine electron probe of CFESEM reduces heat in the sample while significantly increasing resolution.



Dual secondary electron detectors provide high resolution with maximum depth of focus



Specimen Interactions with the Electron Beam

Energy Dispersive X-ray Microanalysis

CFESEM combined with Energy Dispersive X-ray Microanalysis (EDXA) permits morphological and chemical elemental analyses

Results

- Spray droplets, a combination of the fungicide and the tracer, were characterized as unique fibrillar crystals (Figure a) composed of S, Cl and Cu, respectively (Figure b).
- Coverage by the **electrostatic sprayer** (Table 1):
  1. **Significantly more material was deposited on leaves and stubs than on plants treated with the coldfog sprayer.**
  2. **Canopy penetration on upper leaf surface depended on the elevation of the leaf.**
  3. **Uniform deposits on both adaxial and abaxial leaf surfaces was observed.**
  4. **More consistent deposition occurred at the base of plants.**
  5. **Drops ranged from 5-80 µm in size (Figures c & d).**
- Coverage by the coldfog sprayer (Table 1):
  1. **Deposition was significantly less on leaves than on plants treated with the electrostatic sprayer.**
  2. **Coverage was present on the adaxial surfaces, but was generally not observed on the abaxial leaf surfaces.**
  3. **Inconsistent deposition occurred at the base of plants.**
  4. **Deposits ranged from 50-200 µm in size (Figures e & f).**

Table 1. Droplet distribution on target surfaces throughout a greenhouse: Coldfog sprayer vs. electrostatic sprayer as detected by cold field emission electron beam analysis.

Sprayer	Position on Leaf Surface	Plant Number/Location† 1	2	3	4	5	6	7	8	9	1
Electrostatic	Top/ Adaxial	+	+	+	+	+	+	+	+	+	+
	Top/ Abaxial	–	–	+	+	+	+	+	+	+	+
	Middle/ Adaxial	+	+	+	+	+	+	+	+	+	+
	Middle/ Abaxial	+	+	+	+	+	+	+	+	+	+
	Stub	+	+	+	+	+	+	+	+	+	+
Coldfog	Top/ Adaxial	–	+	+	+	+	+	+	+	+	+
	Top/ Abaxial	+	–	+	+	–	–	+	+	–	
	Middle/ Adaxial	+	+	+	+	+	+	+	+	+	+
	Middle/ Abaxial	–	+	–	+	+	+	–	–	+	
	Stub	–	+	+	+	+	+	+	+	+	+

† Distribution is noted by the following: "+" = spray droplets present; "–" = spray droplets absent

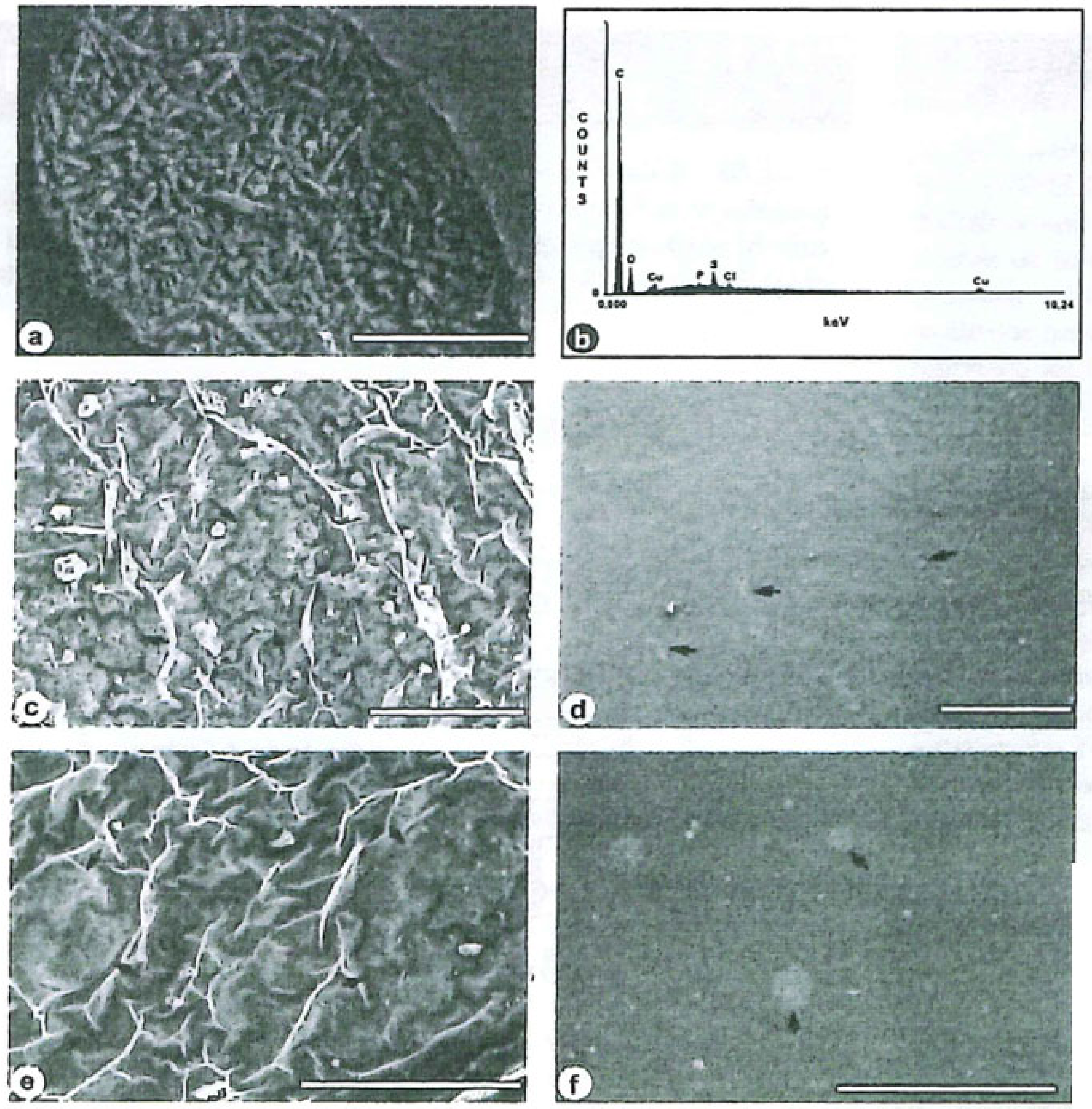


Figure a. A cold field emission scanning electron micrograph of the unique fibrillar crystals (arrows) of the fungicide (copper sulfate pentahydrate) and the tracer (Tinopal) in a droplet. It is representative of the residue observed from either sprayer detected during this study using CFE-EBA, bar = 100 µm. **Figure b.** Energy dispersive x-ray analysis spectrum of the fungicide and tracer droplet shown in *Figure a*. Note that Cl and S are the primary elemental constituents of the tracer and S, Cl and Cu are primary elemental constituents of the fungicide. **Figure c.** Fungicide and tracer droplet residue (arrows) on a *Fuchsia* spp. leaf applied by an electrostatic sprayer, bar = 100µm. **Figure d.** Fungicide and tracer droplet residue (arrows) on an inert stub applied by an electrostatic sprayer, bar = 500µm. **Figure e.** Fungicide and tracer droplet residue (arrows) on a *Fuchsia* spp. leaf surface applied with a coldfog sprayer, bar = 100µm. **Figure f.** Droplet residue (arrows) on inert stub surface applied by a coldfog sprayer, bar = 500µm.

Conclusions

- **The unique operational characteristics of CFE-EBA reduce or eliminate the requirements of specimen preparation.**
- **CFE-EBA yields high resolution images due to the reduced size of the electron probe.**
- **CFE-EBA can acquire data on coverage of fungicide/tracer products.**
- **CFE-EBA can be used to acquire data on efficiency of delivery systems.**
- **The electrostatic sprayer provided significantly more uniform deposits than the coldfog sprayer.**
- **CFE-EBA will permit direct, *in situ* assessments of host-parasite interactions on unprepared hydrated samples and application methods.**