Developing and validating environmentally sound alternatives for the integrated management of moko (*Ralstonia solanacearum*) of plantain (*Musa* sp.) in Colombia

Introduction

Plantain is a staple food in Colombia. Exports although low at present are potentially an important source of foreign exchange. In Colombia, this crop is grown on 350,000 ha throughout the country. Production exceeds 2.5 million tons per year, with 99% destined for the domestic market and the rest for export. In the major production areas—the Coffee Zone, inter-Andean valleys, Colombian Caribbean Region, and the Eastern Plains—the crop has meant an alternative in the face of serious problems of sustainability with other crops. It generates 100 working days per year per hectare, thus improving the quality of life of the inhabitants of these regions.

The central Coffee Zone of Colombia (Departments of Valle, Risaralda, Quindío, and Caldas) is the biggest plantain producer in the country, with an estimated area of 40,000 ha. In this region, together with other plantain-producing areas, associations of small farmers are interested in linking with the market economy and producing cash crops, including plantains. The importance of plantain in marginal regions (Putumayo, Caquetá, Cauca, Nariño) has risen by 20%-30%, stimulating the regional economy.

Moko or banana bacterial wilt, caused by *Ralstonia solanacearum*, is a devastating disease of plantain. It is found throughout Colombia and cuases and estimated annual loss of about US$5.8 million. The problem is compounded by environmental deterioration caused by indiscriminate use of toxic substances such as formol as control agents.

The only controls that farmers currently use are clean seed and cultural practices that are too short term to be really effective in eradicating or detaining the disease.

Objective

This project aims to reduce the impact of *moko* on the plantain crop by generating alternatives for sustainable management, based on improved knowledge of the causal agent. Specifically, the objectives are to:
Identify the minimum inhibitory concentration of 24 substances for disinfecting working tools and soil contaminated with *R. solanacearum*.

Materials and methods

Liquid disinfectants. The following products were used: formol (37% from drugstore); creolin (Cresovec®), phosphoric acid (field, 35%), phosphoric acid (reagent, 85%), bleach (Patojito® = 5% sodium hypochlorite), paint thinner (paint store), Agrodine® Sl, Electowest, Medellin (unexposed, and exposed

to light for 12 h), yodoforo (unexposed, and exposed to light for 12 h), foamy tincture of iodine, lixiviated rachis of plantain obtained through composting (fresh), Ecolife®, lime juice, liquefied sisal leaf , and macerated lime seeds.

Solid disinfectants. Basamid®; freeze-dried, lixiviated rachis of plantain (obtained through composting); urea; calfos; swinglea (100 g of leaves liquefied in a solution of 1 L of 50% alcohol); sisal rib (in fragments); macerated stalks of pencil plant (plant is stripped); and Kocide 101®

Test tubes. Four mL of nutritive broth were added to the first of 14 tubes for each product. To the other tubes of each series, 2.4 mL of nutritive broth were added. Into the first tube, 0.4 mL of the disinfectant to be analyzed was pipetted. For the solid products, 0.4 g were vortex-mixed and 2 mL transferred from the first to the second tube. This procedure was repeated in the following tubes until no. 12 was reached, when 2 mL were discarded. Tube no. 13 had the culture medium and solution (disinfectant), and tube no. 14 had only the culture medium.

Inoculum. Strain 201 (2) 10^{-2}, isolated from soil infected with *moko*, was grown in TZC medium for 24 h at 35°C. To inoculate the test tubes, a base solution of buffer phosphate was prepared with 34 g of monobasic potassium phosphate in 1 liter of distilled water. Then, a 1.25-mL of the base phosphate buffer solution was added to a liter of distilled water. From this solution, 9 mL were added to the test tubes. With this solution, the inoculum was prepared by suspending the bacterium in the buffer. The concentration was prepared to an absorbance of 0.3 in a spectrophotometer at a wave length of 600 nm. With the Neubauer chamber, 2.1×10^8 bacteria/mL were observed. Each tube was inoculated with 0.1 mL of bacterial suspension.

Incubation and evaluation. The tubes were incubated at 25°C under light during the day. After about 60 h, the tubes were evaluated for turbidity. For each product several tubes were cultured in TZC medium to check that the turbidity was caused by *R. solanacearum*. The chemical tests KOH and oxidase were also used.

Results and discussion

Selection of disinfectants for *Ralstonia solanacearum*, causal agent of *moko* in plantain and banana:

> The most effective were formol, Kocide 101®, phosphoric acid (85%), Ecolife®, Basamid®, and phosphoric acid (35%), taking into account the minimum inhibitory concentration (Table 1).
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> According to product cost, formol, calfos, phosphoric acid (35%), lime juice, and Kocide 101® were the most effective. Calfos and lime juice are the most ecological options. These disinfectants need to be

evaluated in the greenhouse and field. Yodoforo, heavily used in the field, is effective only at concentrations of 5% or more.

Among the products for future evaluation are the seeds, juice, and peel of grapefruit; salt; Long Life®; Phyton 27® (bactericide and systemic fungicide); swimming pool chlorine (granulated); detergent Fab®; lixiviate of lime; and noni seed.

Table 1. *In vitro* evaluation of 24 substances for their inhibitory action on the bacterium *Ralstonia solanacearum*.

Cons. no.	Product	US$/unit	Minimum inhibitory concentration (%)	Minimum inhibitory concentration (US$/L)
1	Formol	0.54/L	0.117	0.0006
2	Calfos	0.06/50 kg	5.000	0.0029
3	Phosphoric acid (35%)	1.01/L	0.625	0.0063
4	Lime juice	0.18/L	5.000	0.0091
5	Kocide 101®	7.97/kg	0.156	0.0124
6	Paint thinner	0.58/L	2.500	0.0145
7	Phosphoric acid (85%)	10.87/L	0.156	0.0170
8	Urea (46%)	0.18/50 kg	10.000	0.0176
9	Bleach Patojito®	0.27/gallon	10.000	0.0272
10	Ecolife®	29.00/L	0.234	0.0452
11	Basamid®	14.50/kg	0.322	0.0470
12	Creolin	4.08/gallon	1.250	0.0510
13	Agrodine®, exposed to light	9.24/L	1.250	0.1155
14	Yodoforo	10.87/L	5.000	0.5437
15	Yodoforo, exposed to light	10.87/L	5.000	0.5437
16	Lixiviate of plantain, freeze-dried	7.25/100 g	10.000	0.7249
17	Agrodine®	9.24/L	10.000	0.9243
18	Iodine tincture	20.84/120 mL	10.000	2.0841
19	Sisal rib fragments	0.18/kg	No control	-
20	Leaf extract from sisal	0	No control	-
21	Leaf extract from swinglea (prepared in 50% alcohol)	0	No control	-
22	Lixiviate of plantain, fresh	0.36/L	No control	-
23	Pencil plant	0.18/kg	No control	-
24	Lime seeds	7.25/kg	No control	-

Literature

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