Integrated Management of Black Sigatoka (*Mycosphaerella fijiensis*) And the Nematode Toppling Disease of Plantatins (*Radopholus Similis*) in Organic Production Systems

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Abstract: *Small-holder plantain in Costa Rica are severely affected by both the black sigatoka disease (*Mycosphaerella fijiensis*) and the nematode toppling disease (*Radopholus similis*). Because the chemical option is not easily affordable to most farmers, this study investigated an integrated management strategy based on the sue of EM (effective microorganisms) for black sigatoka control and the use of nematophagous fungi eg. "Nemout" (a cocktail of* Dactylella brochophaga, Arthrobotrys oligospora *and* Arthrobotrys botryospora*),* Paecilomyces lilacinus *and the plant growth promoting rhizobacterium (*Pseudomonas fluorescens*) for control of the toppling disease. Successful sigatoka control was achieved with EM up to flower initiation, with EM treated plants having up to 8 leaves/plant. However, between flower initiation and harvest, additional management measures such as dehanding were needed to produce fruit of export quality. Importantly, the Bokashi alone treatment gave the highest root biomass and yield, both of which were statistically different (P=0.05) from the control.*

Introduction

Plantains (Musa AAB) are a herbaceous perennial crop which provide food, income and employment for many rural communities in the American tropics where they are grown mostly as a subsistence crop, and by extension, less efficiently than bananas, its close relative. While the latter is produced mostly in large commercial plantations with a relatively high level of agricultural inputs including fertilizers and pesticides, plantains are generally grown on small-scale farms by resource-poor peasants with little or no inputs under traditional farming systems. Consequently, yields are low, ranging from 5 tons/ha in mixed-cropped farms to 20 tons/ha under monoculture. Generally, the crop soon becomes unproductive and oftentimes it is abandoned because of a "decline problem" which has been attributed to low soil fertility, poor drainage and pests and diseases. Such problems require that the crop be replanted every 3-8 years (Stover and Simmonds, 1987). Black sigatoka (*Mycosphaerella fijiensis*) is considered one of today's worst threats to banana and plantain production. In Costa Rica alone, the cost of controlling the disease is estimated at $ 17.5 million per year. The disease affects the phtosynthetic ability of leaves and since plants require 8-12 leaves to carry a bunch to maturity, leaf loss due to the disease results in premature ripening and reduced bunch weight (Ploetz, 1999).

The nematode toppling disease (*Radopholus similis*) is equally devastating, affecting the root system and reducing its absorption and anchorage functions. As a consequence, plants become liable to topple over under conditions of heavy rainfall and high winds. Controlling this nematode has resulted in yield increases of 267 percent (Luc et al. 1990). Chemical control of these diseases is not affordable to small-scale growers and neither is it permissible in organic production systems. Host resistance to black sigatoka is now available in some of FHIA's hybrids from

Honduras, but unfortunately these have not been generally accepted by the consumer. For its part, the free exchange of IITA's black sigatoka resistant hybrids is currently restricted due to the risk of disseminating the Banana Streak Virus (BSV). Given these difficulties, a panel of World Bank experts suggested the development of biological control options to complement disease resistance (Persley and George, 1996). With an increasing global demand for organically grown crops, there is surprisingly little research on how to manage diseases under this system. However, the quitinolytic bacterium *Serratia marcescens* and EM (Effective Microorganism) have recently been evaluated for black sigatoka control in Costa Rica with some degree of success. Similarly, the egg-parasitizing fungus *Paecilomyces lilacinus* has shown success in nematode control on several crops (Jatala, 1986). Some nematode trapping fungal species such as *Dactylella* and *Arthrobotrys* also offer interesting control possibilities (Montero Velazco, 1992). A long term goal of making plantain production economically and ecologically sustainable in an organic production system froms the big picture of this study which sought to increase yields through the use of an integrated disease management strategy comprising three components:

a) Using EM to manage black sigatoka
b) Using *Paecilomyces lilacinus*, "Nemout" (cocktail of *Arthorobotrys botryospora, Arthrobotrys oligospora* and *Dactylella brochophaga), Pseudomonas flurescens* (plant growth promoting rhizobacteria) singly and in combinations for the toppling disease management.
c) Using Bokashi for improving plant nutrition and also for managing *Radopholus similis.*

Materials and Methods

A randomized block designed experiment with ten treatments replicated four times was established in 1998 on a field with a history of the nematode toppling disease in the Atlantic zone of Costa Rica (average annual rainfall 3600 mm; average temperature 25-30°C): 600 corms of the plantain variety currare were trimmed and hot water treated for 25 minutes at 55°C and then planted in double rows, spaced at 1.5m between plants, 1m between rows, and 4.5m between double rows.

The following treatments and combination were applied at planting and once every 3 months to the rhizosphere:

a) A granular formulation of *Paecilomyces lilacinus* locally prepared in our laboratory and applied in the planting hole and in the rhizosphere at 25 g/plant.
b) "Nemout" (a mixture of *Arthrobotrys oligospora, Arthrobotrys botryospora* and *Dactylella brochophaga* marketed by Agri-Mart Inc. USA was applied with the aid of knapsack sprayer at 400 g/ha.
c) *Pseudomonas fluorescens*, a plant growth promoting rhizobacterium was cultivated for 48 hours on nutrient broth and applied to the corms in a starch slurry before planting.
d) ECO-HUM, a biostimulant produced from peatimoss, was applied at 2 percent v/v.
e) Furadan at the rate of 10 g/plant served as the control.
f) Using a motorized sprayer, all plants excepting the controls were foliar applied with EM at 1 percent v/v at weekly intervals for black sigatoka control.

g) Similarly, all plants except the control received a bokashi application of 1 kg/plant at 3 monthly intervals. Bokashi was prepared from sawdust, rejected banana fruit, farm yard manure and molasses.

h) Cultural practices including regular weed control, cleaning of drainage canals, pruning of sigatoka infected leaves, bagging of fruit and dehanding were done manually.

Data on the following parameters were taken every 3 months.
Nematode population in roots, percent functional and non-functional roots, root biomass/ treatment at 12 months, average number of leaves/plant and the position of the youngest sigatoka-infected leaf using the methodology of Stover modified by GAUHL, and yield/treatment in tons/ha.
Results were statistically analyzed using the Pc SAS v6 12 programme.

Results and Discussion

Yields of plantains depend mostly on successful management of black sigatoka and the nematode toppling disease. EM-sprayed plants gave and average of 8-9 leaves at flowering compared with 9-11 leaves for commercially-grown plantains receiving fungicides. However, results did not show any statistically significant differences between treatments in terms of leaf numbers and in the position of the youngest sigatoka infected leaf which stood at leaf 6-7. Between flowering and harvest, rapid leaf loss due to black sigatoka reduced leaf numbers to an average of 4-5 healthy leaves, obliging the use of additional management practices such as dehanding to enable the production of fruit of export quality.

EM apparently controls black sigatoka through competition for nutrients and space on the phyllophere. No direct parasitism of ascospores of *Mycosphaerella fijiensis* by EM was demonstrated in laboratory tests. However, an initial inhibition of spore germination and its deformation was attributed to EM's low pH of 3.7-4.1. An apparent delay in symptom expression in field-sprayed plants is still being investigated. Management of the toppling disease (*Radopholus similis*) with nematophagous fungi and other treatment combinations showed no consistent trend in population reduction after one year (Fig. 1). Populations registered in four samplings are above Central America's nematode threshold for bananas (5,000 – 10,000/100 g roots). However, populations fall within the range registered in commercial plantain farms receiving nematicides in Costa Rica (4,000 – 50,000 nematodes/100 g roots). An evaluation of percent functional roots and root biomass (Table 1) showed statistical differences between treatments but these parameters were poorly correlated with yields (R2=0.03: Biomass versus yield).

The Bokashi alone treatment gave the highest yields and root biomass, both of which are statistically different (P=0.05) over the control, which confirms the results of another experiment last year in which a Bokashi treatment proved superior in reducing populations of *Radopholus similis* in bananas.

Luc et al. 1990 recommend the application of large quantities of mulch to stimulate root growth especially after flowering when the root system of plantain seems to rapidly decline. This study confirms that Bokashi apparently improves soil nutrition and texture (Higa and Parr, 1994) and increases root biomass which in turn reduces toppling-over especially during wind storms. Results of the Bokashi treatment are clearly promising and our research will increasingly focus on studying the effects of increasing Bokashi application on nematode management and plantain yields.

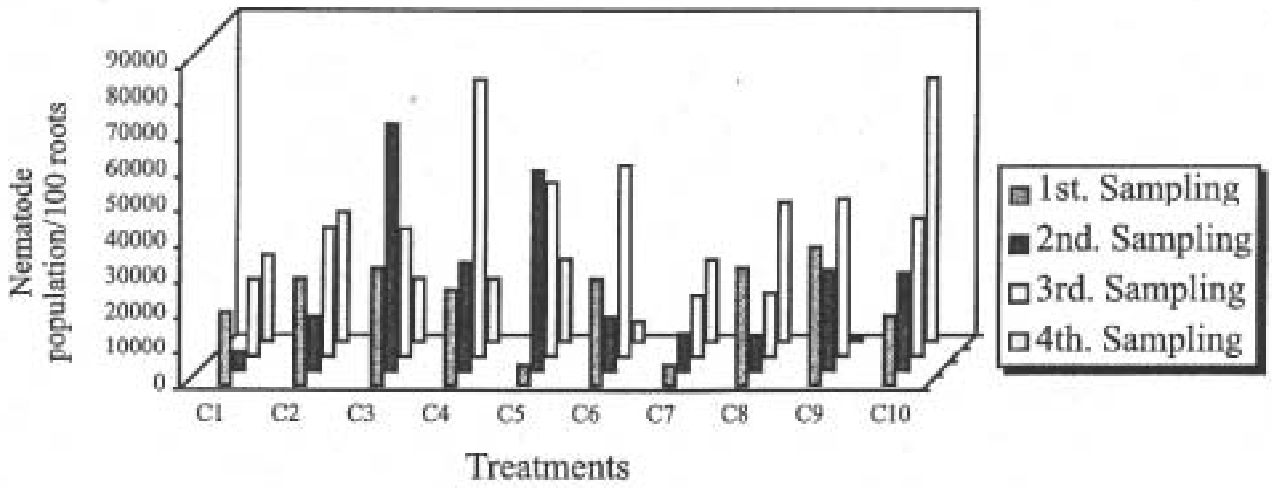

Fig. 1. Population Dynamics of *Radopholus similis*

Key	**Treatments**
C1	Eco Hum + Nemout
C2	*Paecilomyces lilacimus* + Eco Hum
C3	Eco Hum
C4	*Pseudomonas fluorescens*
C5	*Paecilomyces lilacinus* + *Pseudomonas fluorescens*
C6	*Paecilomyces lilacinus*
C7	Furadan (control)
C8	Nemout
C9	Bokashi alone
C10	*Paecilomyces lilacinus* + Nemout

Table 1. Effect of Treatments on Yield

Treatment	**% Functional Roots**	**Root Biomass (Kg/plant)**	**Yield (Tons/ha/yr)**
C1	74Ab	0.55de	10.00abc
C2	73ab	0.98ab	8.20cd
C3	70ab	0.68cd	6.90d
C4	78.5ab	0.38e	9.10bcd
C5	54.5b	0.87abc	7.30d
C6	61ab	0.72cd	10.60ab
C7	73ab	0.43e	8.40bcd
C8	82.5a	0.78bcd	7.00d
C9	77.5ab	1.03a	12.10a
C10	65.5ab	0.9abc	10.00abc

Acknowledgement This study was financed by a grant from the Conservation Food and Health Foundation, Inc.

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