Development of IPM Programs for Plantain System in Ecuador

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Abstract

Integrated pest and disease management practices are under evaluation in the plantain region of Ecuador. El Carmen County is the main reference area, although the main plantain region covers part of the territory of four provinces. In El Carmen, two experiments have been carried out during the last three years with an agreement between the National Institute of Agricultural Research, Tropical Experimental Station at Pichilingue, and the IPM CRSP. One experiment deals with rehabilitation of plantations that have been under poor management for more than 20 years (c 80% of the area), and the other with IPM for new ones, either changing old with new plantings of the same crop or starting a new crop from a pasture or abandoned land.

For rehabilitation, two IPM strategies based on sanitation with and without fungicides are under trial, compared with that recommended by banana export companies, and with farmers practices. In the case of renovation, three factors (varieties, planting system and level of management) known to influence pest and disease incidence are being tested.

Responses in both experiments are measured using levels of damage caused by Black Sigatoka (*Micosphaerella fijeiensis*), and nematodes. Incidence of Black weevils (*Cosmopolites sordidus*) was measured from 1999 till 2001; it was not measured this year due to the lack of response to treatments. Additionally, we are examining the effect on yield including not only actual yield but also the rate of return to harvest (elapsed time between harvest cycles on each production unit).

For this year, values for disease infection were higher than former years, which meant heavier disease pressure for the crop. Under these circumstances, significant differences were still found on the Area Under Disease Progress Curve (AUDPC). Farmers practices had the highest value, followed closely by the export company recommendations from which there was no statistical differences; both IPM treatments showed lowest AUDPC values, and shorter rates of return and highest weight per bunch. Another feature worth mentioning is that during this cycle (the third) a detrimental effect on the plantation for all variables was observed. Parasitic nematodes, namely *Helicotylenchus and Meloidogyne,* the two genera that predominate in the area showed lower counts on both IPM treatments, and beneficial nematodes were frequent and abundant throughout all plots.

On the renovation trial, Black Sigatoka incidence was measured with reference to the youngest spotted leaf, total number of functional leaves and yield. During this harvesting cycle, some differences became evident—for the youngest infected leaf and the number of functional leaves significant differences were found for factors and treatments. The widest difference was between dwarf variety/single row/low management and common barraganete, double row and high management. In general, IPM management with weekly sanitary leaf pruning creates the main differences.

Objectives

Long term: To develop a sustainable IPM Program for plantain under Ecuadorian conditions.

Immediate: to evaluate under on-farm conditions: (1) integrated pest and disease management strategies for plantain; (2) the effects of continuous applications of sanitary practices on the incidence of major insects, nematodes and Black Sigatoka pests on plantain; and (3) to determine the economic benefits of implementing IPM components.

IPM Constraints

Current growing practices throughout the "plantain belt" in the tropical lowlands of Ecuador, around El Carmen and Santo Domingo town, have developed with a minimum use of agrochemicals in general, even after the emergence of Black Sigatoka disease in the late 80´s. However, increased demand has emerged from export companies to control diseases and pests and produce a better quality fruit. Farmers and extension agents recognized Black Sigatoka disease as the main constraint to the crop. The disease exerts a debilitating effect on plants, making them more susceptible to the action of other pathogens like viruses and bacteria.

Another serious constraint is corm damage caused by the larvae of Black weevil (*Cosmopolites sordidus*). This affects the production unit both directly producing low weight bunches, falling down of plants and low emission of new plants. Due to this cause, farmers have only 400 to 500 plants /ha out of 1100 which is the usual planting density. Under these conditions, farmers make very low profit from the crop, having at the most 500 bunches/ha/yr with an average weight of 7 to 12 Kg/bunch.

Poor management practices, limited to two or three weedings per year and cleaning of plants and harvest residues at different intervals (when demand increases price of the fruit, farmers apply sanitary and chemical measures) also contribute to low yields. Plantations over 25 years since establishment and changing weather conditions add more constraints to the crop. The area and the crop suffers from lack of technical support and poor information. Attempts have been made to adapt technology from banana to plantain with a poor reception from farmers, mainly due to the high inputs (labour, chemical, money) required.

The following hypotheses are being tested in this study: (1) application of improved agronomic practices help reduce the impact of diseases and pests in plantain monoculture systems in Western Ecuador**;** (2**)** applications of IPM practices allow recovery of productivity of old plantations even after a devastating event such as El Niño; and (3) the benefits of improved integrated management through IPM practices may become evident from the second crop generation.

Research Methods

Two experiments have been established to cover the alternatives that a farmer has on the plantain belt with crops of more than 15 years of age: (a) rehabilitation and (b) renewal. The following tactics are under trial: In the first case (rehabilitation), the technical package recommended for banana by the export companies was put into trial in comparison with an integrated management plan with and without fungicides. For the second trial (renewal of old plantations or new plantings) three factors (varieties, planting system, and levels of management) are being tested.

Both experiments were established in a typical farm of the region, called "Santa Marianita" (Carranza family), San Agustin parish, Canton El Carmen, Manabi province, Ecuador (42 Km west from Santo Domingo). The area is located around 250 meters above sea level, has an average temperature of 24^0C and 2900 mm of annual rainfall. Usually the rainy season lasts 6 to 7 months, being misty and generally overcast the remaining 5 months.

Rehabilitation trial

Control strategies recommended by the export companies in the region use two tactics: weekly sanitary leaf pruning, meaning removal of any leaf with 50% or more of the area infected and "burn" or necrosado by *M. fijensis*; fungicide application with Benomyl (280 g/ha), Tilt (0,4 lt/ha) and Calixin (0,6 lt/ha)--two successive sprays each, at monthly intervals, in mixture with agricultural oil (15 lt/ha) + Agral 90 (100 ml/ha) in 35 l of water. The tactics constitute one treatment on the rehabilitation trial (Export Co. treatment). This level of management includes occasional trapping of black weevils to attempt to reduce population of the insect; weed control with Glyphosate, no nematicide and leaving 3 to 4 and even more re-growth or daughter plants per production unit.

Treatments 2 (IPM with fungicides) and 3 (IPM without fungicides) refer to our proposal of integrated management of the crop based on the scarce knowledge about the plantain-*M. fijensis* pathosystem. Treatment 4 was the typical management used by farmers which consists of 2 or 3 annual weedings, light cleaning of the plants once a year (dead leaves and choupon removal) and one or two harvests every month, according to fruit available or farmer needs.

The IPM practices included in treatments 2 and 3 (IPM) were: leaf surgery (removal of only the necrosado area) every 15 days and management of the pruned leaves on the ground to avoid inoculum dispersal. The same fungicide program as for treatment 1 was used, but with intervals of 45 days. Monthly trapping of weevils was conducted, using "V" traps prepared with newly harvested plantain pseudostems 0.15 m above ground, cut on V shape at the top. Weed management used either "machete" or natural cover of the soil by *Geophila macrophoda*, a native weed present in the experimental plots with a very superficial root system which does not compete with the crop. When it was considered necessary, the herbicide Finale (Glufosinate) was applied to avoid continuous use of Glyphosate that is common and toxic to plantain. Fertilizer was applied following soil analysis; cleaning of the pseudostems or "deschante"; selection and ordering of the productive units to cover empty areas, managing suckers. Three sequential productive units were left, instead of 5 to 8 that are common; during the first year of trial (1999) empty areas were progressively replanted. Since the plantation recovered, approximately six months after treatment began, harvest was regular at fortnightly intervals.

The treatments were distributed in a randomized complete block design with 4 repetitions. Due to the variable number of plants on each plot, data were taken on 10 plants/treatment/repetition. Suckers of around 6 weeks old were marked, and distributed randomly on each plot, taking care to avoid border effect due to lack of competition.

Response variables: Black Sigatoka

Disease index. - Following Stover's scale of 6 points, modify by Gauhl[1] a disease index is calculated that takes into account the incidence and severity (measured as the percentage of affected tissue) on every leaf of a plant with the exception of the "candle" (un-open leaf), and those that are broken down. A combination of the degree of incidence per leaf and the number of infected leaves/plants gives the severity of the disease or "**disease index**".

The youngest infected leaf. Gives an indication of the progress of the disease. It is an average of the total youngest leaves with visible symptoms from the plants under evaluation. The younger the leaf infected, the larger the incidence (and severity) of the disease.

Area Under the Disease Progress Curve (AUDPC)[2]. The disease index that quantifies the amount of disease over time was used to measure values of AUDPC. We employed an epidemiological model designed to quantify relative amounts of disease on time according the following formula:

$$\mathbf{AUDPC = \sum[(Y_2 + Y_1)/2)/(T_2 - T_1) + \ldots\ldots\ldots.n + Y_{n-1})/2)\ X\ (T_n - T_{n-1})]}$$

Where: Y_1 and Y_2 are successive evaluations of infection on T_1 and T_2 times.

Black weevil and nematodes. Monitoring of insects, mainly *C. sordidus* every month and nematode populations twice a year, throughout. For nematodes the severity of diseased roots is measure using a scale develop for Triviño[3]:

Little or no damage	=	< 25% of infected roots
Moderate damage	=	25 to 50% infection
Severe damage	=	50 to 75% infection
Very severe	=	> 75% infection

Rate of "return" (from one generation to the next) to harvest (or harvesting cycles per unit). The time in days required by every successive unit ("mother" to "daughter" to "granddaughter") to produce its respective "bunch" .

Yield. Number of plantain bunches and weight per plot.

Variable costs. All labor and materials (mainly agrochemical) used on every treatment are recorded and priced. They will be used as a reference to calculate the cost/benefit ratio of each treatment, and the increment of treatments in relation to the control (farmer's).

Renovation Trial

This experiment considers two varieties, two levels of management and two planting systems. (a) Varieties were "barraganete common" widely used in the area and dwarf barraganete, introduced by PROEXAN as resistant to Black sigatoka. (b) Levels of management were: "conventional," including use of Glyphosate for weed control, and leaf pruning every 15 days, cutting leaves with 50% or more necrosis by Sigatoka. "IPM management" keeps the ground cover and uses local spraying of herbicide "Finale", and sanitary pruning every week, cutting only those parts of the leaf "burned" by the fungus. (c) Planting systems were single rows of plantain planted at 2.5 x 2.5 m (i.e. 1600 plants/ha) and double rows, with two plants together planted at 2.5 m x 3m (i.e. 2867 pls/ha).

The combined factors gave a total of 8 treatments. Each treatment had 12 plants for evaluation. The following treatments were evaluated:

T1 = Dwarf plantain, double row, conventional management **(V1S2M1)**
T2 = Dwarf plantain, double row, IPM management (**V1S2M2**)
T3 = Dwarf plantain, single row, conventional management (**V1S1M1**)
T4 = Dwarf plantain, single row, IPM management (**V1S1M2**)
T5 = Common plantain, double row, conventional management (**V2S2M1**)
T6 = Common plantain, double row, IPM management (**V2S2M2**)
T7 = Common plantain, single row, conventional management (**V2S1M1**)
T8 = Common plantain, single row, IPM management **(V2S1M2)**

Treatments were distributed in a randomised complete block design with 4 repetitions, arranged as a split plot, with varieties and planting systems as main plots and level of management as subplots. Variables considered for evaluation were taken only on juvenile (from 4-5 leaves till before flowering) plants and were: **incidence** of Sigatoka in terms of functional leaves, using a six point scale (0= no infection) that considers as functional a leaf with disease symptoms up to point 3 on the scale; **intensity** of the disease, measured as the youngest infected leaf; (YIL) **yield**, as No. and weight of bunches; and **rate of return**, calculated in terms of No. of days between one harvest to the next on every production unit.

Apart from treatments, all plots were managed with regular practices recommended for the crop, as sucker removal, leaving only two for every unit, and cleaning of old leaves and sheaths from pseudostems. Monthly traps were used to

[1] GAUHL, F. 1989. Epidemiología y Ecología de la Sigatoka negra (*Mycosphaerella fijensis*, MORELET) en plátano (Musa spp.) en Costa Rica. Traducido al español por Espinoza, Jaime. Union de Países Exportadores de Banano (UPEB) Panamá. 126p.

[2] SHANER, G. & FINNEY, R.E. 1977. Phytopathology 67: 1051-1056.

[3] TRIVIÑO, C. 1999, personal communication.

evaluate Black weevil population; and soil and root analysis twice a year helped monitor nematode populations. No attempts were made to control either of them.

Results

Rehabilitation trial

Black Sigatoka disease

Despite higher infection values this year, differences between treatments became clear, with the two IPM options having lower levels of infection (Table 1) significantly different from Export Co. recommendations as applied by farmers, and the usual farmers practices (Control).

Table 1. Area under the disease progress curve for Black Sigatoka (*M. fijiensis*) on Barraganete plantain. Four treatments during three periods of evaluation. Rehabilitation Trial. INIAP-IPM/CRSP. El Carmen, September, 2002.

Treatments	2000	2001	2002
Export Co.	**11308.3 a**	**8099.2 b**	**10858.4 a**
IPM + Fungicides	**10878.3 a**	**7375 a**	**9488.9 b**
IPM + No Fung.	**11127.9 a**	**7543.3 ab**	**9741.1 b**
Control	**12591.4 b**	**9017.7 c**	**11348.6 a**
CV %	**2.85**	**3.29**	**4.95**

Differences in numbers between the two IPM treatments due to fungicide spraying are not significant. Considering that, on the Export Co. treatment, the fungicide was applied at shorter frequencies (30 days, against 45 in IPM + F) we find evidence that this component is not having a significant impact on the disease. However its action becomes evident when we analyze the Youngest infected leaf (Table 2), the fungicide treatment seems to be more favorable. It is evident as well, that fungicide is of little use without complementary management practices, as shown in table 2, with Export Co. and Control treatments having similar YIL values. YIL values and total number of leaves affect yield, weight, and rate of return. Both variables gave significantly different values for IPM treatments, while in this cycle Export Co. and farmers showed lower weights and longer rates of return (days) (Table 3).

Monitoring of nematodes showed interesting results as can be seen in Figure 1. Both IPM treatments render the lowest number of nematodes, considering only plant parasitic genera. On the other hand, *Helicotylenchus* sp reached highest values with 2300 each for treatments Export Co. and Control, followed well behind by *Meloidogyne*, which reached 900 /100 cc of roots on the former.

Table 2. Youngest Infected Leaf Values in the Rehabilitation trial. El Carmen, Ecuador. INIAP-IPM CRSP, 2002.

Treatments	Youngest Infected Leaf (YIL)
Export Co.	**3.67 b**
IPM + Fungicide	**4.21 a**
IPM No Fungicide	**4.03 ab**
Farmer (Control)	**3.66 b**
CV %	5.82

Values followed by the same letter are not statistically different. Duncan, α= 0.05.

Table 3. Average weight (Kg) per bunch and rate of return (days) in days to harvest in the Rehabilitation trial. El Carmen, Ecuador. INIAP-IPM CRSP, 2002.

Treatments	Average Weight(Kg)/bunch	Return (days)
Export Co.	10.07	375 a
IPM + Fungicide	11.88	281 c
IPM No Fungicide	10.80	278 c
Farmer (Control)	9.69	325 b
CV		12.96

Values followed by the same letter are not statistically different. Duncan, α= 0.05.

Figure 1. Plant parasitic Nematodes on 100 g of roots. Rehabilitation trial. El Carmen, Ecuador. INIAP-IPM CRSP, 2002

The corresponding soil analysis of each treatment gave a different picture. *Meloidogyne* is the most abundant genera with nearly 300 specimens for 100 g of soil from all treatments, except the Export Co. treatment that showed only 100; *Helicotylenchus* was as well represented, as were beneficial nematodes. It is important to note the quantities of beneficials, mainly from the genus *Dorylaimus* (70% of the population found), in all treatments (Figure 2). Apart from the treatment effect, it was noted that certain areas of one repetition of treatment Export Co. were on clay soil. These findings coincide with observations where a relationship between type of soil and nematode genera were present; heavy soils seem to favour *Meloidogyne*, while *Helicotylenchus* and *Radopholus* are more common on lighter soils.

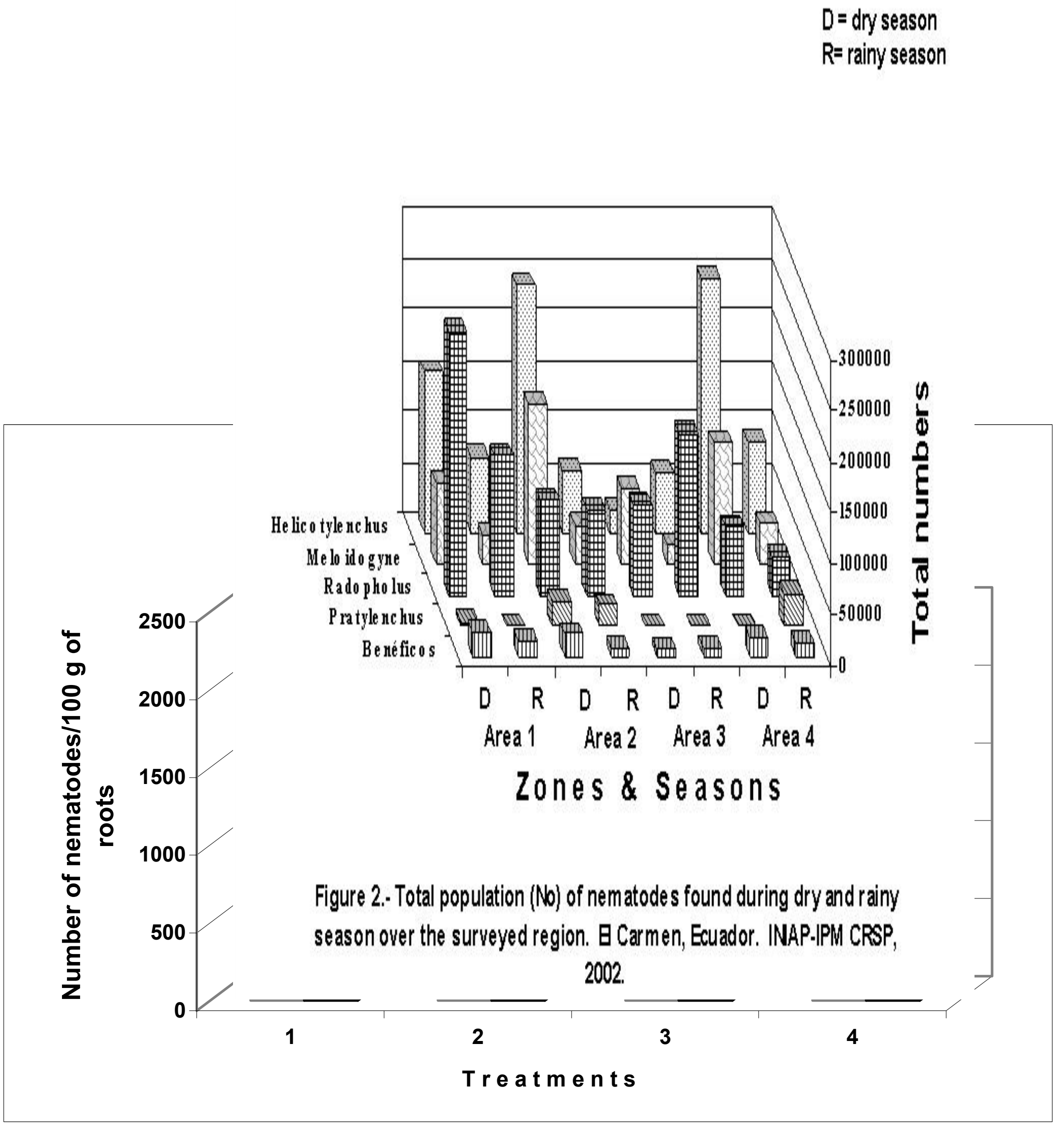

Figure 2.- Total population (No) of nematodes found during dry and rainy season over the surveyed region. El Carmen, Ecuador. INIAP-IPM CRSP, 2002.

Renovation trial.

Black Sigatoka. The youngest infected leaf value observed on treatment 8 was clearly different from all other treatments where Conventional Management (M1) was applied (Table

4). This difference however is not big enough to ensure that plants reach the flowering stage with the minimum accepted number of 8 to 10 leaves.

As can be seen in Table 5, bunch weight fell in the third cycle below that of the first cycle, with a range of 9.07 to 12.07 Kg, while in the first there were 10.02 to 11.92 and in the second we reached a maximum of 11.87 to 14.89, very close to the 12 and 15 Kg considered to be the acceptable average bunch weight. Another interesting fact observed is that for the third cycle, the harvested period is enlarged, because while from October 2000 to September 2001, 95% of the best treatments were harvested, the following period (October 2001 to Sept. 2002) only 77% of the fruits on the same treatments were harvested.

Table 4. Statistical differences between treatments for the variables YIL and FL. Renovation Trial. El Carmen, Ecuador. September, 2002. INIAP-IPM CRSP.

Treatments	Mean values of Youngest infected leaf (YIL)		Number of Functional Leaves (FL)	
1. V1S2M1	4.20	c	5.40	c
2. V1S2M2	4.41	a b c	5.77	a bc
3. V1S1M1	4.30	b c	5.66	bc
4. V1S1M2	4.36	a b c	5.60	bc
5. V2S2M1	4.32	b c	5.71	a bc
6. V2S2M2	4.52	a b	5.87	a b
7. V2S1M1	4.19	c	5.43	c
8. V2S1M2	**4.61**	**a**	**6.12**	**a**
C.V.	3.89 %		4.90 %	

Values followed by the same letter are not statistically different. Duncan, $\alpha = 0.05$.

Table 5. Duncan Multiple Rank Tests for average weight (Kg) of bunches and percentage of harvested plants/harvesting cycle. Renovation Trial. El Carmen, Ecuador. INIAP-IPM CRSP, 2002.

	HARVESTS CYCLES					
TREATMENTS	First		Second		Third	
	Weight / bunches (kg)	Harvested Plants %	Weight / bunches (kg)	Harvested Plants %	Weight / bunches (kg)	Harvested Plants %
1. V1S2M1	11.33 a	87.50 a	14.00 a	73.99 b	10.67 a	72.90 a
2. V1S2M2	11.82 a	93.74 a	13.13 a	92.91 a	10.36 a	77.08 a
3. V1S1M1	11.92 a	93.74 a	14.89 a	95.24 a	12.07 a	77.05 a
4. V1S1M2	11.02 a	89.58 a	13.57 a	95.83 a	9.800 a	64.58 a
5. V2S2M1	10.11 a	84.41 a	12.32 a	64.66 bc	9.070 a	58.33 a
6. V2S2M2	10.75 a	83.33 a	12.07 a	87.07 a	9.850 a	58.33 a
7. V2S1M1	10.53 a	85.41 a	11.87 a	61.66 c	9.570 a	54.18 a
8. V2S1M2	10.84 a	83.33 a	12.02 a	70.41 bc	9.470 a	70.83 a
C.V.	10.76 %	11.76 %	8.60 %	8.96 %	17.77 %	25.38 %

Although there were no significant differences, the dwarf variety gave heavier bunches, but its quality was not good for export, the same as happened the previous year.

Impact

IPM may have an important role in rehabilitation of old plantain plantations. Its effect on lower rates of Black Sigatoka and higher yields with very little chemical input is very attractive to farmers. IPM strategies as followed on these trials keep populations of plant parasitic nematodes under control and increase beneficial ones. Although variations in the cost/benefit relationship may be the ultimate decision factor between rehabilitation or renovation (renewal) of plantain, results on these trials present farmers the possibilities of selecting either of them once the factors involved are clarified.

Networking Activities

Relationships with INIBAP have been established. Scientists from Central America and Colombia have shown interest in knowing results of the El Carmen trials. The local association of Banana and Plantain, CONABAN, has used the experimental plots as demonstration of some of the practices under trial. The plantain team participates in the organization and discussion of a Forum around plantain problems where we received requests for validation and demonstration trials with our best results. Contacts have been made with groups of Private Technical Assistance organizations of the area-CODAPEC and others, the Cooperativa Agroartesanal El Carmen and the staff of the Proyecto de Tecnología Agropecuaria-PROMSA-and there is now fluid communication related to problems of the crop.

Students from three Universities of the region have shown interest in communication exchange with personnel of the project in order to do complementary research. Pichilingue is becoming a source of information for a systematic network of research that is emerging around this crop due to actual interest shown by exporters and farmers.

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Training output

Danilo Vera C. is doing his MSc studies in Vicosa University, Brazil, financed by PROMSA resources.

Jose Cedeño and Randy Rivera participated in a course about “clean technologies for plantain” in the Dominican Republic. They had the opportunity of discuss experience and results derived from IPM CRSP trials in Ecuador with other scientists.

Students appointed to the project benefit from training sessions about field techniques with Drs. Wills Flowers and Roger Williams.

Project Highlights

It has been established that management of infected leaves complemented by agronomic and sanitary measures on old plantain plantations may substantially improve yield, minimize damage from Black Sigatoka disease and keep the nematode population in a healthy equilibrium.

Fungicide use either at 30 day intervals is not affecting Black Sigatoka disease, particularly when it is not accompanied with improvement of the plantation. The same fungicides, even when used at large intervals (45 days), keep one extra leaf on the plant and make a difference on the total number of leaves required at the flowering stage.

The technical expertise of INIAP personnel has been improved in their capability to do research and to understand problems around a difficult growing system that involves all levels of farmers.

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