OUTPUT II. PEST AND DISEASE MANAGEMENT COMPONENTS AND IPM STRATEGIES AND TACTICS DEVELOPED

Sub-output 1. An Integrated Control Method for Cassava Root Rots in Colombia (E. Alvarez)

Activity 1. Evaluation of hot-water treatment of cassava cuttings, and the effect on CBB in the field at Santander and Quindío

Cuttings from three cassava varieties growing in Quindío Department, affected by cassava bacterial blight (CBB), were treated to evaluate the severity of CBB on shoots and saprophytes on stakes. Cuttings were immersed in water at 49 °C for different times (thermotherapy), given 5 minutes immersion in a chemical suspension (Captan, 1.5 g/Lt and Benomyl, 1.5 g/Lt) or Ecolife® 1 cc/Lt (suspension from citrus seed).

Previous treatment by thermotherapy for 10 min, 24 h before thermotherapy during 1 h, and thermotherapy for 49 min without pre-treatment, did not affect the number of shoots/cuttings nor shoot length. In CM 523-7 and HMC-1, thermotherapy increased the number of shoots per stake. Using thermotherapy for a long time increased the presence of saprophytes on stakes. Ecolife and chemical treatment were not effective in controlling saprophytes grown when cuttings were treated by thermotherapy. Although CBB severity was low, in HMC-1 (the susceptible variety) CBB had 1.8 on the severity scale, while thermotherapy over a long time after pre-treatment decreased the disease more than thermotherapy at 1 h after pre-treatment or 49 min without pre-treatment.

Table 1.1. Effect of cassava-cuttings treatment by thermotherapy to control saprophytes and *Xanthomonas axonopodis* pv. *manihotis* affecting stakes.

Variety	Treatment	Shoot length (cm)	Shoots/Cutting	Saprophytes on Stakes[a]	CBB[a]
CM 523-7	10 min + 1 h	25.6	5.0	1.5	1.3
CM 523-7	10 min + 2 h	14.3	4.2	1.8	1.2
CM 523-7	10 min + 3 h	10.3	4.4	1.8	1.0
CM 523-7	10 min + 4 h	6.0	2.4	1.8	1.2
CM 523-7	10 min + 5 h	1.1	0.6	2.5	1.0
CM 523-7	10 min + 5 h + Ecolife	0.0	0.0	3.0	-[b]
CM 523-7	10 min + 5 h + chemical	0.0	0.0	4.0	-
CM 523-7	5 h	4.9	1.3	2.0	1.5
CM 523-7	5 h + chemical	0.3	0.4	2.2	1.0
CM 523-7	49 min	24.7	3.7	1.7	1.7
CM 523-7	49 min + Ecolife	18.7	4.2	1.3	1.6
CM 523-7	49 min + chemical	17.9	4.8	1.3	1.6
CM 523-7	Ecolife	18.7	4.3	1.7	1.7
CM 523-7	Chemical	27.1	3.4	1.2	1.4
CM 523-7	Control	23.2	3.0	2.3	1.4
HMC -1	10 min + 1 h	15.4	5.0	2.2	1.4
HMC -1	10 min + 2 h	18.0	4.4	2.0	1.2
HMC -1	10 min + 3 h	5.9	4.8	2.3	1.3
HMC -1	10 min + 4 h	1.0	1.4	2.3	1.0
HMC -1	10 min + 5 h	0.1	0.3	3.0	1.0
HMC -1	10 min + 5 h + Ecolife	0.0	0.0	4.0	-

Variety	Treatment	Shoot length (cm)	Shoots/Cutting	Saprophytes on Stakes[a]	CBB[a]
HMC -1	10 min + 5 h + chemical	0.0	0.0	4.0	-
HMC -1	5 h	0.0	0.0	1.0	-
HMC -1	5 h + chemical	0.0	0.0	2.0	-
HMC -1	49 min	21.0	7.0	2.0	1.0
HMC -1	49 min + Ecolife	14.7	4.4	1.7	1.2
HMC -1	49 min + chemical	14.3	4.0	1.2	1.2
HMC -1	Ecolife	12.0	2.5	2.0	1.0
HMC -1	Chemical	16.5	4.4	1.8	1.4
HMC -1	Control	19.1	4.0	2.0	1.8
M Per 183	10 min + 1 h	18.8	4.6	1.5	1.2
M Per 183	10 min + 2 h	13.9	5.6	1.5	1.0
M Per 183	10 min + 3 h	14.3	6.6	2.0	1.0
M Per 183	10 min + 4 h	8.8	3.2	2.2	1.0
M Per 183	10 min + 5 h	2.0	1.6	2.0	1.0
M Per 183	10 min + 5 h + Ecolife	0.4	0.8	1.3	1.0
M Per 183	10 min + 5 h + chemical	0.8	0.5	2.0	1.0
M Per 183	5 h	0.2	0.3	2.0	1.0
M Per 183	5 h + chemical	0.0	0.0	2.3	-
M Per 183	49 min	11.0	5.0	2.0	1.0
M Per 183	49 min + Ecolife	12.1	5.4	1.8	1.0
M Per 183	49 min + chemical	13.9	6.0	2.0	1.3
M Per 183	Ecolife	14.3	4.5	5.0	1.0
M Per 183	Chemical	14.8	3.8	1.7	1.0
M Per 183	Control	11.3	4.4	2.0	1.4

[a] Scale: 1= no incidence, 5= high incidence and severity.
[b] Stakes not germinated.

Activity 2. Evaluating practices for managing root rots in cassava

To evaluate those crop management practices that, in previous studies, have shown promise in reducing root rots, we conducted trials with the active participation of farmers and UMATA technicians in the Departments of Cauca and Quindío.

2.1. Department of Cauca

In the Department of Cauca, two trials were established in the village districts of San Jerónimo and Mondomito, Municipality of Santander of Quilichao, to evaluate the control of some practices over *Phytophthora* spp., fungi which induce root rot.

The following treatments were evaluated for their effect on the incidence and severity of root rots:

Treatment

1 2.5 t/ha chicken manure + 300 kg/ha of the chemical fertilizer Agropremix® (15% N, 10% P_2O_5, 12% Zn, 2% B, 0.75% Cu, 3% S, and 0.01% of Mo)
2 2.5 t/ha chicken manure + potassium sulfate (180 kg/ha K_2O)
3 2.5 t/ha chicken manure + potassium chloride (180 kg/ha K_2O)
4 2.5 t/ha chicken manure + thermotherapy (stakes immersed in water heated over a wood fire to 49°C for 49 min)
5 *Trichoderma* strain 14PDA-4 (1×10^4 conidia/mL)
6 *Trichoderma* strain 19TSM-3A (1×10^4 conidia/mL)
7 Cassava variety La Reina (CM 6740-7)
8 Stake selection
9 2.5 t/ha chicken manure (traditional farmer's practice)

For all treatments, chicken manure was incorporated at 2.5 t/ha. The cassava regional variety Verdecita (M Col 1505) was planted with vegetative seed obtained from a farm located in San Jerónimo, where the disease was present. The two best strains of the *Trichoderma* fungus were selected to control *Phytophthora* spp. in *in vitro* tests and in the greenhouse. Cassava stakes were inoculated with *Trichoderma* by immersion for 10 min in a suspension with a concentration of 1×10^4 conidia/mL. We then applied 100 mL of the suspension at the base of each plant, and again every 45 to 60 days throughout the crop's cycle. Stakes were selected for their health and from the middle parts of stems.

The experimental design used for these plantings was a randomized complete block design with three replicates and 20 plants per treatment. Treatment 6 was applied only in San Jerónimo.

Following farmers' customs, for the San Jerónimo trial, dolomitic lime was applied at 500 kg/ha and fertilizers were applied 35 days after planting. In contrast, in Mondomito, fertilizers were applied at planting and no lime was applied. The performance of the elite genotype CM 6740-7 ('La Reina') was evaluated.

In the Santander de Quilichao trial, heat treatment did not affect germination (data not shown). The 'Verdecita' planting material was of lesser quality, whereas 'La Reina' had a high germination rate.

Plant height and stake production per plant were greatest when the trial was fertilized with Agropremix. **Table 2.1** shows the effect of the treatments on yield and incidence of rotten roots. All treatments surpassed the control in stake production per plant. Yield under all treatments in San Jerónimo was very low because of low-fertility soil and the plot's history of six cassava crops previous to the trial. Chemical fertilization did not increase yield, whereas treatments with *Trichoderma* 14 PDA-4 and selection of stakes improved yields by 33.6% and 25.8%, respectively, although root-rot incidence was higher than for the control. In contrast, *Trichoderma* 19 TSM-3A helped reduce root rots. Potassium sources also helped reduce rots. The variety La Reina showed no root rots.

The Mondomito trial could not be harvested because of public order problems.

Table 2.1. Effect of root-rot management on yield and incidence of rotten roots, Farm "Villa Fernanda", San Jerónimo Village District, Santander de Quilichao, Cauca.

Treatment	Plant Height (m)	Stake Production per Plant	Yield (T/ha.)	Root Rot Disease: Incidence (% Affected Plants)	Root Rot Disease: Severity (Kg. Affected Roots/ha.)	Root Rot Disease: Percentage of Affected Roots
Agropremix	2.1	10.2	3.63	14	183	4.8
K_2SO_4	1.9	8.4	3.2	5	50	1.5
KCl	2	8.5	3.6	5	67	1.8
Stake selection	2	9.4	4.38	4	150	3.3
Thermotherapy	2	8.2	3.95	23	150	3.7
Control, traditional farmer's practice	1.9	7.9	3.48	16	100	2.8
Trichoderma strain 14PDA-4	2	8.6	4.65	17	175	3.6
Trichoderma strain 19TSM-3A	2	9.1	3.15	5	33	1.0
Cassava variety Reina (CM 6740-7)	2.8	8.4	5.15	19	0	0.0

2.2. Department of Quindío

The different control practices for *Phytophthora* spp. were evaluated for disease incidence and severity, and for yield in four field trials in the Municipalities of Montenegro and La Tebaida.

Two experiments were established on the Farms "El Jardin" (La Tebaida) and "Guayaquil" (Montenegro) to evaluate the effect of some management practices for controlling *Phytophthora* spp. Variety HMC-1 was used, and the treatments were as follows:

Treatment

1 Fertilization with KCl (180 kg/ha K_2O).
2 Fertilization with K_2SO_4 (180 kg/ha K_2O).
3 Farmer fertilization: Farm "El Jardin" applied 350 kg/ha of a mixture of ammonium sulfate and borax at a rate of 50:1.5; Farm "Guayaquil" applied 500 kg/ha of a mixture of Nitrax-DAP-KCl at a rate of 1:2:2. Fertilizers were applied 45 days after planting.
4 Stakes given thermoterapy (49°C for 49 min).
5 Stakes immersed for 5 min in Orthocide® (captan, 4 g/L of the commercial product) and Ridomil® (metalaxyl, 3 g/L of the commercial product).
6 Stakes immersed in Lonlife® (ascorbic acid) at 4%.
7 Biological control: stakes immersed for 10 min in a suspension of *Trichoderma* (1×10^4 conidia/mL), strains 19TSM-3A and 41 PDA-3A. The area around the stake was treated with 100 mL/plant of the fungal suspension.
8 Varietal resistance, using genotypes 'HMC-1', 'ICA Catumare', 'M Per 183' ('Peruana'), and the local variety 'Chiroza' (M Col 2066).

The experimental design was a randomized complete block design, with three replicates and 20 plants per treatment. The treatments with thermoterapy and *Trichoderma* were as described for the trials in Cauca (Treatments 4, 5, and 6).

The highest yields were obtained with the crop management practices suggested by CIAT: stake immersion and periodic applications of a suspension of the biological agent *Trichoderma* strain 14 PDA-4. Compared with local practices, applications of potassium sulfate and potassium chloride improved yield. The incidence of drying was only 13% (scale of 2 or 3), a low level for evaluating the effects of treatments. In general, germination and plant development were good. The application of Micobiol® increased plant height considerably **(Table 2.2)**. The percentage of germination in the Quindío trials was reduced by heat treatment (40%-68.3%), compared with the same treatment in Cauca (98.3%), probably because the temperature at the bottom of the oil drum was too hot, being higher than 49°C. These results suggest that more trials should be carried out to adjust the technique. Old and/or very thin stakes are probably more negatively affected by temperatures.

Table 2.2. Effect of stake treatments, including hot water, biocontrol, chemical control, fertilizers, and varietal resistance, on cassava development, root rot disease, and cassava bacterial blight in a trial established in the Department of Quindío, Colombia.[a]

				Bacterial Blight		Root Rot Disease		
Control Practices	**Plant Height (m)[b]**	**Root Yield (T/ha.)**	**Number of Stakes per Plant**	**Incidence (% Affected Plants)**	**Severity (%)**	**Incidence (% Affected Plants)**	**Severity (T Affected Roots/ha.)**	**% Affected Roots**
Variety HMC-1								
Thermotherapy[c]	1.73	62 a	36 a	21 a	89	2 a	3.7 a	5.6
Biocontrol with Trichoderma spp.[d]	1.89	63 a	36 a	16 a	89	2 a	1.8 a	2.8
Micobiol®[e]	2.31	60 a	37 a	12 a	56	1.3 a	0.2 a	0.3
Ridomil (metalaxyl)	1.91	70 a	39 a	16 a	89	1.7 a	1.0 a	1.4
Potassium chloride (KCl)	1.90	70 a	37 a	18 a	100	2 a	0.3 a	0.4
Potassium sulfate (K_2SO_4)	1.90	80 a	38 a	24 a	100	2 a	1.1 a	1.4
Local varieties								
Manzana	1.93	41 a	36 a	21 a	100	2 a	7.1 a	14.8
HMC-1	1.86	51 a	37 a	22 a	100	1.8 a	6.1 a	10.7

a. Duncan's multiple range test, alpha <= 0.05.
b. At 7 months after planting.
c. Oil drum on wood fire, with the water's temperature at 49ºC for 49 min.
d. Strain 14 PDA-4.
e. Contains *Trichoderma* spp., *Beauveria bassiana*, *Metarhizium anisopliae*, *Verticillium lecanii*, *Paecilomyces fumosoroseus*, *Hirsutella thompsonii*, and *Bacillus thuringiensis.*

Germination of plants treated with thermotherapy was very low (26.7%-68.3%; **Table 2.3**), compared with the same treatment in Cauca (98.3%). The temperature was possibly inappropriate because a different container was used to that in the Cauca experiments. At Farm "El Jardin", the highest cassava yield was obtained with 'ICA Catumare', which surpassed by more than 20 t/ha the varieties HMC-1, Chiroza, and M Per 183, whose yields ranged between

32.0 and 38.7 t/ha. At Farm "Guayaquil", 'ICA Catumare' and 'HMC-1' surpassed 'Chiroza' (**Table 2.4**).

Table 2.3. Germination rate of cassava on three farms, Quindío, Colombia[a].

Treatment	Farm			Average
	El Jardín	Las Mercedes	Guayaquil	
Fertilization				
KCl (30 g/plant)	88.3	66.6	96.7	83.9
K_2SO_4 (36 g/plant)	91.7	95	95	93.9
Control of the farmer[b]	91.7	85	88.3	88.3
Control without fertilization	93.3	93.3	86.7	91.1
Stake Treatment				
Thermotherapy (49ºC during 49 min)	40	26.7	68.3	45.0
Orthocide® (4 g/L) + Ridomil® (3 g/L)[c]	100	96.7	73.3	90.0
Longlife® 4%	-	-	96.7	96.7
Biological Control				
Trichoderma (strain 19TSM-3A)	88.3	98.3	95	93.9
Trichoderma (strain 41PDA-3A)	96.7	71.7	90	86.1
Varietal Resistance				
HMC-1	100	100	91.7	97.2
ICA Catumare	88.3	86.7	89.8	88.3
M Per 183	93.3	95	-	94.2
Chiroza	93.3	83.3	70	82.2

a. All treatments, except Treatment 7, used variety HMC-1.
b. Farm "El Jardin": ammonium sulfate + borax (50:1.5) at 300 kg/ha. Farm "Guayaquil": Nitrax-DAP-KCl (1:2:2) at 500 kg/ha.
c. At Farm "Guayaquil", Orthocide® was replaced by copper oxychloride.
d. Oil drum on wood fire, with the water's temperature at 49ºC for 49 min.

Farmers' fertilization management, which involved high doses, led to the highest yields, but also to the highest incidence of root rots. Although Farm "Guayaquil" obtained the higher yield (28.9 t/ha) with the *Trichoderma* strain 41 PDA-3A, it was not consistent with what happened on Farm "El Jardin", where yield (28.3 t/ha) was much lower than the control without fertilizer (47.9 t/ha; **Table 2.5**).

When potassium sulfate was used, root rots were not present. Stake treatment with Longlife® led to the greatest reductions of root rots. The varieties most affected by root rots were Chiroza and M Per 183, whereas variety HMC-1 had the least root rots. The *Trichoderma* strain 19 TSM-3A helped perceptibly to reduce root rots, although the resulting yields were not good (**Table 2.5**).

At Farm "El Jardin", 65-day-old plants were affected by the bacterium *Xanthomonas axonopodis* pv. *manihotis* in some treatments. The bacterium was not present in treatments with K_2SO_4, thermotherapy, nor in the genotypes 'ICA Catumare' and 'Chiroza', which have shown acceptable resistance to the disease, whereas 'HMC-1' and 'M Per 183' are susceptible. As the crop aged, incidence of the bacterium became insignificant.

Table 2.4. Effect of management practices for root rots on plant growth in cassava, Farm "El Jardin", La Tebaida, Quindío, and Farm "Guayaquil", Montenegro, Quindío.

Treatment	El Jardín		Guayaquil		Average	
	Plant Height (m)	No. of Stakes/ Plant	Plant Height (m)	No. of Stakes/ Plant	Plant Height (m)	No. of Stakes/ Plant
Fertilization						
KCl (180 Kg/ha K_2O)	1.81	8.4	2.14	9.9	1.98	9.2
K_2SO_4 (180 Kg/ha K_2O)	1.92	10.3	1.92	7.1	1.92	8.7
Control farmer[a]	1.88	11.8	1.86	8.9	1.87	10.4
Control without fertilization	1.89	10.1	1.89	9.2	1.89	9.7
Stake Treatment						
Thermotherapy (49°C during 49 min)	1.92	9.7	1.86	6.5	1.89	8.1
Orthocide® (4 g/L) + Ridomil® (3 g/L) [b]	1.74	9.0	1.85	8.7	1.80	8.9
Lonlife® 4%	-	-	2.14	8.5	2.14	8.5
Biological Control						
Trichoderma strain 41PDA-3A	1.75	8.2	2.07	7.7	1.91	8.0
Trichoderma strain 19TSM3A	1.88	10.7	1.92	6.9	1.90	8.8
Varietal Resistance						
Chiroza	2.59	18.3	2.34	17.2	2.47	17.8
HMC-1	1.81	10.7	2.30	10.5	2.06	10.6
Ica Catumare	2.03	11.0	2.80	13.9	2.42	12.5
M Per 183	1.82	10.2	-	-	1.82	10.2

At Farms "Las Mercedes" and "El Jardin", where incidence of cassava bacterial blight is high, some 35-day-old plants were evaluated as being affected by *Xanthomonas axonopodis* pv. *manihotis* in treatments with KCl, farmers' control, *Trichoderma* spp., chemical control, and in genotypes 'M Per 183' and 'HMC-1'.

2.3. Comparing Departments

Table 2.6 compares selected trials carried out during the project. Thermotherapy of cassava stakes before planting and the use of *Trichoderma* are practices that have a good effect on yield. The use of KCl is recommended for Quindío. The variety La Reina (CM 6740-7) is a very good option for farmers in Cauca. The Chiroza, the variety traditionally planted in the Eje Cafetero, produced much less than did 'ICA Catumare' or 'HMC-1'.

Table 2.5. **Effect of root-rot management practices on yield and on incidence of rotten roots at the Farms "El Jardin" (La Tebaida, Quindío) and "Guayaquil" (Montenegro, Quindío).**

	El Jardín			Guayaquil			Average		
	Root yield	Roots affected by Root Rot		Root yield	Roots affected by Root Rot		Root yield	Roots affected by Root Rot	
Treatment	**(T/ha)**	**(Kg/ha)**	**(%)**	**(T/ha)**	**(Kg/ha)**	**(%)**	**(T/ha)**	**(Kg/ha)**	**(%)**
Fertilization									
KCl (180 Kg/ha K_2O)	42.6	0	0.0	23.4	439	1.8	33	220	0.7
K_2SO_4 (180 Kg/ha K_2O)	29.9	0	0.0	22.3	0	0.0	26.1	0	0.0
Control of the farmer[a]	50.5	0	0.0	23	1869	7.5	36.8	935	2.5
Control without fertilization	47.9	0	0.0	19.2	575	2.9	33.6	288	0.8
Stake Treatment									
Termotherapy (49ºC/ 49 min)	35.1	123	0.3	20.8	1768	7.8	28	946	3.3
Orthocide® (4 g/L) + Ridomil® (3 g/L)[b]	37.3	0	0.0	27.9	514	1.8	32.6	257	0.8
Lonlife® 4% (ascorbic acid)	-	-	-	23.4	114	0.5	23.4	114	0.5
Biocontrol with Trichoderma									
Strain 41PDA-3A	28.3	0	0.0	28.9	247	0.8	28.6	124	0.4
Strain 19TSM 3A	32.4	0	0.0	14.7	41	0.3	23.6	21	0.1
Varietal Resistance									
Chiroza	38.6	0	0.0	15.5	3086	16.6	27.1	1543	5.4
HMC-1	38.7	0	0.0	25.2	24	0.1	32	12	0.0
ICA Catumare	59.5	597	1.0	28.9	1028	3.4	44.2	813	1.8
M Per 183	32	3009	8.6	-	-	-	32	3009	8.6

[a] Farm "El Jardin": ammonium sulfate + borax (50:1.5) at 300 kg/ha. Farm "Guayaquil": Nitrax-DAP-KCl (1:2:2) at 500 kg/ha.

[b] At Farm "Guayaquil", Orthocide® was replaced by copper oxychloride.

Table 2.6. **Cassava yield under management for root rots. Averages across five trials established in the Departments of Quindío and Cauca, Colombia.**

Treatment	Root yield (T/ha)						
	Quindío				Cauca		
	Montenegro (Cantores)	Montenegro (Guayaquil)	La Tebaida (El Jardín)	Average	Santander de Quilichao (San Jerónimo)	(El Turco)	Average
Thermotherapy	62	21	35	39.3	4	15	11.5
Trichoderma	63	22	30	33.5	3.9	-	3.9
KCl	70	23	43	45.3	4	-	4
K_2SO_4	-	22	30	26	-	9	9
Manzana	41	-	-	41	-	-	-
Chiroza	-	15	39	27	-	-	-
La Reina (CM 6740-7)	-	-	-	-	5	-	5
Ica Catumare	-	29	59	44	-	-	-
HMC-1	-	25	39	32	-	-	-
M Per 183							
Farmer [a]	51	23	51	41.7	4	15	9.5

[a] Montenegro and La Tebaida: HMC-1; Santander de Quilichao: Verdecita

Activity 3. Effect of soil physico-chemical properties on cassava root rot

Three samples of cassava roots were taken during the harvesting of the trial carried out in the rural community of San Jerónimo near Santander de Quilichao (Cauca, Colombia). Each sample consisted of a combined sample of roots from a replicate of the eight test treatments. Replicate 1 consisted of cassava plants planted in the highest part of the test lot, which was located on a steep slope; replicate 2 was located in central part of the test plot; and replicate 3 in the lowest part of the test plot.

Based on the chemical analysis of cassava roots (**Table 3.1**), Fe, Mn, and Zn contents increased in a downward direction on the slope, where nutrient content is expected to be higher. Although fertility is expected to improve downwards on the slope, cassava yields and root rot decreased perhaps because Fe and Mn increased to levels that affected yields by interfering with the absorption of other nutrients. The coefficient of correlation between yield and Fe, Mn, and Zn contents was, respectively, -0.61, -0.99, and -0.91 (**Table 3.2**). The coefficient of correlation between percentage plants suffering root rot and Fe, Mn, and Zn contents was, respectively, -0.57, -0.99, and -0.89. The correlation between percentage rotten roots/plant was also high and negative for these same elements. Plans are to establish trials to analyze whether these elements increase the resistance to root rot.

Table 3.1. Chemical analysis of cassava roots and soils in a field trial carried out in Santander de Quilichao (Colombia), with three replicates.

Chemical Analysis of Roots				Chemical Analysis of Soils[a]		
	No. of Replicate					
Element	1	2	3	Element[b]		Qualitative Assessment
N (%)	0.220	0.250	0.260	-	-	-
P (%)	0.062	0.067	0.064	Assimilable phosphorus (ppm)	25	-
K (%)	0.595	0.610	0.670	Exchangeable potassium (meq/100 g)	0.29	-
Ca (%)	0.106	0.092	0.112	Exchangeable calcium (meq/100 g)	3.1	-
Mg (%)	0.068	0.072	0.099	Exchangeable magnesium (meq/100 g)	1.2	-
Fe (ppm)	93.3	141.7	201.3	Fe (ppm)	85.1	High
Mn (ppm)	5.49	4.71	7.01	Mn (ppm)	5.8	Intermediate
Cu (ppm)	2.27	2.40	2.20	Cu (ppm)	2.5	Intermediate
Zn (ppm)	4.90	4.83	6.91	Zn (ppm)	2.6	Intermediate
B (ppm)	2.67	2.23	2.17	B (ppm)	0	Low
S (%)	0.018	0.045	0.036	S (%)	-	-
Yield (t/ha)	4.09	4.06	3.64			
Rotten roots (%)	2.80	3.70	1.03			

[a] Trial average.
[b] '–' means not determined.

Table 3. 2. Coefficients of correlation between productivity, root rot, and chemical analysis of roots.

	Chemical analysis of roots[a]			
Evaluation parameter	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
Growth and productivity				
Established plants (%)	0.55	0.98	0.88	-0.11
Plant height (m)	0.87	0.96	1.00	-0.55
No. of stakes/plant	0.46	0.96	0.83	-0.01
No. of commercial roots/plant	-0.81	-0.98	-0.99	0.46
Weight of commercial roots/plant (kg)	-0.81	-0.98	-0.99	0.46
Yield (t/ha)	-0.61	-0.99	-0.91	0.19
Root rots				
Plants with rotten roots (%)	-0.57	-0.99	-0.89	0.13
Rotten roots/plant (%)	-0.80	-0.99	-0.99	0.43
Plants with dry buds (%)	0.05	0.75	0.51	0.41

[a] Correlation.

Activity 4. Biological control of root rots in cassava

Evaluating *Trichoderma* in soils of the Departments of Cauca and Quindío, Colombia.

To better understand the dynamics of *Trichoderma* populations in the soil, samples of soil were taken on four farms during the harvesting of trials.

Samples of soil (3 g each) were taken from each cassava plot established in the field that had been inoculated with *Trichoderma* strains and also from the non inoculated check (numeral 2), and then diluted in 27 ml distilled water (base solution) and serial dilutions prepared (from 10^{-1} to 10^{-4}). Each dilution was agitated by vortex and placed on 0.1 ml V8A and PDA culture media; 100 □g/ml penicillin, 25 □g/ml chlortetracycline, 100 □g/ml PCNB, and 25 □g/ml Bengal Rose were added. Petri dishes were incubated at room temperature with light. *Trichoderma* colony counts were performed up to two weeks after placement in culture media.

Table 4.1 shows that 19TSM-3A is the *Trichoderma* isolate that survives longest in the soil. Previous greenhouse trials indicate that a population of 10^4 CFUs/g soil is sufficient to respond to mild attacks of soil pathogens such as *Phytophthora* or *Fusarium*. However, *Trichoderma* concentrations in the soil should be built up periodically. Inoculating stakes at planting also proves very beneficial. The effect of soil on *Trichoderma* spp. populations was not significant. Plots where *Trichoderma* had not been applied presented a relatively high natural population, although lower than inoculated plots. In Cauca, the natural population of *Trichoderma* is low probably because of the soil's low organic matter content. Although the use of molecular markers could improve the detection of *Trichoderma*, it is still impossible to quantify these populations with these tools.

A high correlation was observed between yield and concentration of *Trichoderma* in the soil. The correlation with root rot incidence, although negative, was not very high, indicating that the evaluated strains do not affect pathogen control significantly. On the contrary, strain 41PDA-3A showed a correlation of 1.0 with root rot, indicating that plots with higher concentrations presented greater root rot (**Table 4.1**).

Tabla 4.1. Evaluating *Trichoderma* in soils of the Departments of Cauca and Quindío, Colombia, inoculated with this fungus.

		Treatment			
		Isolate			
		19TSM-3A	41PDA-3A	14PDA-4	Non Inoculated Check of *Trichoderma*
Municipality	**Farm**	***Trichoderma* (cfu/g Soil)**			
La Tebaida	El Jardín	4.1×10^4	2.3×10^4	-	5.9×10^3
Montenegro	Guayaquil	5.7×10^4	3.9×10^4	-	2.7×10^3
Santander de Quilichao	San Jerónimo	3.9×10^3	-	3.1×10^4	9.3×10^1
Santander de Quilichao	Mondomito	-	-	1.9×10^3	1.0×10^3
Average		3.4×10^4	3.1×10^4	1.7×10^4	2.4×10^3
Yield		**Yield (t/ha)**			
La Tebaida		32.4	28.3	-	50.5
Montenegro	El Jardín	14.7	28.9	-	23.0
Santander de Quilichao	Guayaquil San Jerónimo	3.15	-	4.65	3.48
Average		16.8	28.6	4.65	25.7
Correlation[a]		0.59	1.0	-	0.99
Root Rots		**Rotten Roots (%)**			
La Tebaida	El Jardín	0	0	-	0
Montenegro	Guayaquil	0.28	0.85	-	8.13
Santander de Quilichao	San Jerónimo	1.05	-	3.76	2.87
Average		1.33	0.43	3.76	2.55
Correlation[b]		-0.36	1.00	-	-0.40

[a] Coefficient of correlation between yield and concentration of *Trichoderma* in soil.
[b] Coefficient of correlation between rotten roots and concentration of *Trichoderma* in soil.

Activity 5. Controlling *Sphaerotheca pannosa*, causal agent of powdery mildew of rose in Colombia

Introduction

Sphaerotheca pannosa var. *rosae* (Wallr.) Lév., the causal agent of powdery mildew, is a major pathogen of roses. Disease symptoms develop quickly, affecting flower quality and causing significant economic losses. Control measures include foliar applications of fungicides to reduce pathogenic inoculum. Increasing public and scientific awareness of the need for a healthy environment has encouraged the development and evaluation of new disease control measures to replace fungicides in integrated management strategies. The use of biofungicides directly affects environmental protection and, in the future, could replace the more expensive chemical fungicides. Interest in using alternative disease control methods in flowers has grown, not only because of society's continuing demand for reduced pesticide levels in greenhouse drainage water, but also because of the limited availability of resistant, commercially acceptable plants. Control methods to replace agrochemical applications should be economical, sustainable, durable, and able to control several diseases. Foliar applications of biocompatible fungicides may reduce the development of powdery mildew, for example IT was demonstrated that the foliar application of phosphate salts reduced the incidence of powdery mildew in *Rosa indica* by 79%.

In spite of being an insecticide, neem derivatives affect diseases, including rose mildew and black spot. Other biopesticides based on plants are extracts of garlic, beggar's ticks (*Bidens pilosa*) and castorbean (*Ricinus communis*).

Pastor-Corrales reported the inhibitory effect of leaf extract from tabog (*Swinglea glutinosa*) on the causal agent of anthracnose (*Colletrotrichum lindemuthianum*) and Ascochyta blight in beans. This study aims to evaluate a plant extract and several fertilizers for their effectiveness in reducing populations of *S. pannosa* var. *rosae* and in controlling disease development in roses under greenhouse conditions.

Materials and Methods

Validating the use of swinglea extract, foliar fertilizers, and fungicides for controlling *S. pannosa* in rose crops

In the first semester of 2001, six experiments were established at the farms "El Ciprés" (Gachancipá), "Megaflor" (Madrid), and "La Valvanera" (Chía), in the Department of Cundinamarca, Colombia. At "El Ciprés", four experiments were carried out on cultivars Aalsmeer Gold and Charlotte to validate the efficiency of each of 6 methods of controlling powdery mildew. At the other two farms, different packages or combinations of these have being evaluated for disease control on cultivar Aalsmeer Gold.

At the beginning of each experiment, the rose beds were heavily inoculated with the pathogen. The high inoculum pressure meant that, for these experiments, there was no need to artificially inoculate the plants. Some selected beds received no disease control throughout the experiment.

At "El Ciprés", spray applications of the various control products were carried out on all stems in selected plots, using a motor pump (Maruyam) with two nozzles and automatized pressure between 25 and 30 pounds. Foliage was wetted completely with a given product every 7 days.

Applications in Madrid and Chía were done with a 1-L pump, which was pressurized manually. Every 4 days, only selected and marked stems for evaluation were sprayed. Between 1 and 2 L were needed per plot for each application.

Products evaluated in the Sabana de Bogotá

To prepare swinglea extract, healthy leaves of shrubs established at CIAT (Palmira, Valle del Cauca) were cut. We used 100 g of swinglea leaves per liter of drinking water; then liquefied the leaves and strained them through six layers of gauze. Before application, we added 1 mL/L of Inex-A® solution as a dispersing agent and adherent. For the experiments in Madrid and Chía, 50% ethanol was used to obtain the active ingredient in greater quantities. Because of problems of plant poisoning in some rose plants, the quantity of swinglea leaves was decreased from 100 to 30 g/L. Between applications, the extract was stored in cold rooms at 2ºC on the farms.

The following foliar fertilizers were evaluated: monobasic potassium phosphate (KH_2PO_4, 13.6 g/L) and dibasic potassium phosphate (K_2HPO_4, 17.4 g/L). After observing plant poisoning, dosage was dropped to 8 and 7 g/L for monobasic potassium phosphate and dibasic potassium phosphate, respectively (experiments 3 and 4 at "El Ciprés"). In Chía and Madrid, two doses of monobasic potassium phosphate were evaluated: 8 and 1.5 g/L **(Table 5.1)**. Sodium phosphate (16.1 g/L) was not assessed because this high dosage can cause plant poisoning in roses.

In these two municipalities, we are also evaluating phosphoric acid (1 mL/L) and Nutriphite® (2 mL/L; assimilable phosphorus 434.0 g/L, soluble potassium 403.0 g/L; Biagro Western Sales, Visalia, CA, USA).

Treatments were carried out with Elosal® (80% elemental sulfur at 1 mL/L), Rubigan® (0.6 mL/L), Stroby® (kresoxim-methyl, 0.25 mL/L), and Meltafun® (Meltatox or dodemorph, 2.5 mL/L). We also applied a mixture of Meltafun® with Rubigan® (fenarimol, equal dose). We added 1 mL/L Inex-A® to all treatments, except the two with Rubigan®.

The efficiency of plant washings was also evaluated, using large quantities of water.

Activity 6. Evaluating fungicides, swinglea extract, and foliar fertilizers under greenhouse conditions, CIAT, Palmira

To date, we have established five experiments, each with treatments using healthy and infected plants. At CIAT, the effectiveness of the fungicides mentioned previously is being evaluated. Under favorable conditions, pressure of pathogen inoculum is high and artificial inoculations have been carried out only occasionally. The treatments are applied weekly (experiments 1-3) or every 3 days (experiments 4 and 5). The effectiveness of an extract, frozen and conserved at -20ºC for 3 months, was compared with fresh extracts. Extracts obtained with 50% ethanol and 50%, 25%, and 10% thinner were also included.

Products evaluated at CIAT, Palmira

The following products were evaluated for their efficiency in controlling powdery mildew:

Swinglea extracts diluted in:

- Water (100 g/L)
- 50% ethanol
- 50% acetone
- 25% thinner
- 10% thinner

Swinglea extracts:

- Pulverized (after drying at 55ºC overnight) and diluted in water
- Pulverized (after drying at 55ºC overnight) and diluted in 50% ethanol
- Frozen and conserved at -20ºC for 3 months, then prepared in water
- Mixed in a solution of water and monobasic potassium phosphate (13.6 g/L)

- Mixed in a solution of water and dibasic potassium phosphate (17.4 g/L)

Resistance inducers (fertilizers):

- Dibasic potassium phosphate (17.4 g/L)
- Monobasic potassium phosphate (13.6 g/L)

Fungicides:

- Rubigan® (0.6 mL/L)
- Stroby® (0.25 mL/L)
- Elosal® (1.0 mL/L)

Biofungicides (based on plant extracts):

- Laurel (*Laurus nobilis*)
- Hairy beggar-ticks (*Bidens pilosa*)
- French marigold (*Tagetes patula*)

The last two plant extracts were fermented for 6 h in 50% ethanol.

Biological products:

- Lixiviated worm compost (200 mL/L)
- Citric emulsion (2.5 mL/L)
- Ecolife® (1.5 mL/L)
- Lixiviated banana bunches fermented with *Acetobacter* spp. under anaerobic conditions
- Lixiviated compost of fruits and vegetables (to 50%) such as red pepper, tomato, grape, Andean blackberry, pineapple, eggplant, melon, yellow passionfruit (Grajales S.A., La Unión, Valle del Cauca) for about 3 months

Negative control was drinking water.

Evaluations

The Sabana de Bogotá

In each plot, we evaluated 20 stems ("El Ciprés") or 9 stems ("Megaflor" and "La Valvanera"), previously identified. The stems selected were those with the largest number of infected leaves. Each stem was numbered, using tape. These plants were not harvested until the experiment was completed. The stems located at the extremes of each plot and close to streets were not included in the evaluations. Each stem was evaluated for severity of powdery mildew according to the following scale:

1 = Healthy stem
2 = Some leaves on the infected stem show mild leaf symptoms,

beginning infection (lesions between 4 and 6 mm in diameter), only 1 to 2 leaves infected

3 = Stem moderately infected, lesions being larger than 7 mm on more than 2 leaves and appearing white

4 = Most leaves on the stem are infected, the area infected per leaf is relatively large, the disease attacks both leaves (more than 3) and stem, as much as half the leaf surface infected

5 = Many infected leaves, leaves totally invaded, with small colonies on more than 5 leaves per stem.

Leaves that had very small colonies of the fungus were recorded as infected. Data were stored on Excel, a computerized program for calculation.

At the end of each experiment, we evaluated incidence, number of infected leaves per stem, and sporulation (scale of 1 to 3, where 1 = no sporulation and 3 = abundant sporulation).

CIAT, Palmira

For the experiments at CIAT, we evaluated incidence, number of infected leaves per stem, and sporulation (scale of 1 to 3, where 1 = no sporulation and 3 = abundant sporulation).

Experimental Design

For all experiments in the Sabana de Bogotá, the experimental design of randomized complete blocks was used. Each trial had three blocks or replicates. A treatment was assigned at random to each plot. At CIAT, the experiments were carried out with two or three blocks.

Statistical Analysis

We used the statistical package SAS to carry out an analysis of variance for each experiment, and determined significant differences according to Duncan's $\alpha = 5\%$.

Results

Validating the use of swinglea extract, foliar fertilizers, and fungicides for controlling *S. pannosa* in rose crops

At "El Ciprés", six methods of control were evaluated under conditions of very high pressure from powdery mildew inoculum on two rose cultivars. Each experiment was repeated twice. The swinglea extract reduced incidence and severity in all experiments in "El Ciprés" **(Table 6.2)**.

The swinglea extract prepared with drinking water lowered disease incidence and the number of infected leaves per plant, especially in cultivar Charlotte. However, no significant difference in susceptibility was detected between 'Aalsmeer Gold' and 'Charlotte'.

The treatments with the monobasic and dibasic potassium phosphates fared better than those with Stroby® and Rubigan®. Monobasic potassium phosphate was slightly more effective than dibasic potassium phosphate, and was better than Stroby®, because it reduced the rate of increase in incidence and severity. Reducing the dosage of monobasic phosphate from 13.6 to 8 g/L did not diminish its effectiveness in controlling powdery mildew.

Chemical treatment with Stroby® was more effective than with Rubigan®. Elosal® had the least effect on the disease. Differences between treatments were greater for 'Charlotte' than for 'Aalsmeer Gold'. The biofungicides best controlled disease in cultivar Charlotte. For cultivar Aalsmeer Gold, differences among treatments were not detected, although the biofungicides were slightly more effective than chemical treatment with Stroby®.

In two experiments at Madrid and Chía, doses of the products used were reduced to prevent plant poisoning. Washings with water were also included. These experiments also included combinations of different control methods **(Table 6.1)** to reduce the problem of plant poisoning. The swinglea extract is now prepared with alcohol (50% ethanol), because it does not induce plant poisoning and extracts a larger volume of the active ingredient. The final concentration of alcohol is 30 mL of 50% ethanol per liter of swinglea extract. At "Megaflor" (Madrid), disease incidence and severity in cultivar Aalsmeer Gold were reduced by an application of swinglea **(Table 6.3)**. A mixture of Meltafun® and Stroby® was the most effective treatment at the two farms. Monobasic phosphate did not control the disease. No plant poisoning was observed on the farms when the modified extract of swinglea and monobasic potassium phosphate were used together. Plants under chemical control, cultural control, and the expensive integrated control in the three replicates presented green lesions that were either circular or long and narrow extending from leaf base to tip.

Note, however, that the fungicides Stroby® and Rubigan® did not control the disease effectively. That no treatment, including Stroby® and Rubigan®, lowered disease incidence or severity is of concern, even though they did reduce the rate of increase in the disease. The reason is that most of the experiments were carried out with beds carrying many infected stems, most of which were very unhealthy. The experiments indicate that initiating control while disease incidence is still low is more effective. With the more frequent applications used at "Megaflor" and "La Valvanera", for example, applications every 3 days instead of 7, efficiency of control improved. That is, the short time between infection by and sporulation of *S. pannosa* is taken into account. In the experiments at Madrid and Chía, Meltafun® was also evaluated. This fungicide was not available in Colombia when the experiments at Gachancipá were established.

Table 6.1. Treatments realized at experiments in the farms Megaflor (Madrid) and La Valvanera (Chía), Cundinamarca Department.

Treatment	Day of Evaluation and Application					
	Day 1	Day 4	Day 8	Day 12	Day 16	Day 20
Chemical control	Meltafun and Stroby	Rubigan	Meltafun	Rubigan	Meltafun and Stroby	Rubigan
Biocontrol[a]	Swinglea extract	Swinglea extract	Swinglea extract	Swinglea extract	Swinglea extract	Swinglea extract
Cultural control	Monobasic potassium phospate (8 g/L)	Phosphoric acid	Nutriphite	Washing	Monobasic potassium phospate (8 g/L)	Phosphoric acid
Integraded control, expensive option (chemical, biological and cultural control)	Meltafun and Stroby	Swinglea extract	Monobasic potassium phospate (8 g/L)	Meltafun	Swinglea extract	Monobasic potassium phospate (8 g/L)
Integraded control, economic option (chemical, biological and cultural control)	Elosal	Swinglea extract	Monobasic potassium phospate (1.5 g/L)	Washing	Elosal	Swinglea extract

[a] At CIAT currently other plant extracts are being evaluated for their efficiency to control the disease which offers different options for biocontrol.

Table 6.2. Evaluation of time in use of swinglea extract, foliar fertilizers, and fungicides to control powdery mildew in rose cultivar Aalsmeer Gold (experiments 1 and 2), "El Ciprés", Gachancipá, Cundinamarca, Colombia.

Treatments	Area below the Disease Progress Curve[a,b]			
	Aalsmeer Gold		Charlotte	
	Incidence[c]	Severity[d]	Incidence[e]	Severity[f]
Swinglea extract	594 a	36 a	129 a	27 a
Monobasic potassium phosphate	407 a	30 a	160 a	28 a
Bibasic potassium phosphate	608 a	40 a	90 a	27 a
Stroby	759 a	41 a	135 a	36 ab
Rubigan	741 a	38 a	294 b	48 b
Elosal	773 a	41 a	409 c	34 ab
Average	647	38	203	33

[a]Duncan multiple range test α=5%;
[b]Plants were evaluated 0, 9 and 16 days. After each evaluation the different products were applied;
[c]Variation coefficient = 28% and R^2 = 0.71;
[d]Variation coefficient = 17% and R^2 = 0.51;
[e]Variation coefficient = 30% and R^2 = 0.87;
[f]Variation coefficient = 29% and R^2 = 0.53.

After one semester of the project's second phase, we conclude that swinglea extract and monobasic potassium phosphate are effective (comparing the results obtained in six field experiments) low-cost alternatives, with very low toxicity to humans. In contrast, the chemical treatments Stroby® and Rubigan®, which are widely used in the Sabana de Bogotá, belong to the high toxicological categories I and II, respectively.

As explained in "Materials and Methods", more evaluations are being carried out to determine the efficiency of each control method and their efficiency when combined in different packages for disease management. In the second semester, experiments will also be established on different farms to analyze the effect of different genetic groups found on the farms on the efficiency of control methods.

Table 6.3. Evaluation of the use of different technological packages to control Powdery Mildew of the cultivar Aalsmeer Gold at the Farms Megaflor (Madrid) and La Valvanera (Chía) (Experiments no. 5 and 6).

Treatments		Disease Progress[a]					
	Control Practice	Farm Megaflor		Farm La Valvanera		Average	
Package[b]	Applied Day 4	Incidence[c]	Severity[d]	Incidence[c]	Severity[d]	Incidence[c]	Severity[d]
Economic integrated control	Elosal	30	-0.27	-103	-0.03	-37	-0.15
Biocontrol	Swinglia extract	11	-0.29	11	0.07	11	-0.11
Expensive integrated control	Meltafun and Stroby	26	-0.24	15	-0.31	20	-0.28
Chemical control	Meltafun and Stroby	30	-0.49	19	-0.21	24	-0.35
Cultural control	Monobasic potassium phosphate	26	1.93	22	0.02	24	0.97
Average		25	0.13	-7	-0.09	8	0.02

[a] Difference between d=4 and d=0;
[b] See Table 1 for more information;
[c] Percentage of the stems affected by Powdery Mildew;
[d] Range between 0 and 3, average of the stems affected, 0=healthy, without sporulation; 3=high sporulation.

Evaluating fungicides, swinglea extract, and foliar fertilizers under greenhouse conditions, CIAT, Palmira

To generate new alternatives for managing powdery mildew, CIAT is continually evaluating, in the greenhouses, the efficiency of plant extracts, resistance inducers, lixiviation, and others. Those practices that are currently the most efficient are being evaluated on farms.

We found we could improve the swinglea extract **(Table 6.4)**. The mixture of swinglea diluted in a solution of water and monobasic potassium phosphate is a highly efficient alternative, taking into account the considerably diminished percentage of infected leaflets per plant, and was more effective than chemical treatment with Rubigan®. This suggests that the combination of two mechanisms that act differently may increase effectiveness in disease control.

Table 6.4. Evaluating fungicides, swinglea extract, and foliar fertilizers for controlling powdery mildew in rose cultivar Konfetti under greenhouse conditions at CIAT (experiment 1), Palmira. The experiments were initiated with two infected plants and two healthy plants per treatment.

	% of Foliolos Affected per Plant					
Treatment	**Day 0**	**Day 14**	**Difference Between Days 14 and 0**	**Day 21**	**Difference Between Days 21 and 0**	**Average Differences**
Mixture of swinglea prepared in water and monobasic potassium phosphate	41	0	-41.4	25	-16.4	-28.9
Rubigan (0.6 ml/L)	86	63	-22.6	76	-10.0	-16.3
Swinglea extract prepared with 50% ethanol	35	8	-26.5	31	-4.0	-15.2
Drink water	73	63	-10.4	63	-10.2	-10.3
Monobasic potassium phosphate (17.4 g/L)	27	14	-12.8	21	-6.0	-9.4
Lixiviated earthworm compost (200 ml/L)	0	0	0.0	9	9.4	4.7
Monobasic potassium phosphate (13.6 g/L)	32	15	-16.8	66	34.2	8.7
Citroemulsion (2.5 ml/L)	3	0	-2.8	26	23.7	10.5
Swinglea extract prepared with water (100 g/L)	18	4	-13.6	62	44.7	15.5
Elosal (1 ml/L)	6	2	-3.7	44	38.2	17.3
Pulverized swinglea extract prepared with water (dried at 55° C during one night)	9	8	-0.5	48	39.5	19.5
Average	53	30	-22.7	43	-9.3	-16.0

The results obtained at CIAT show that extracting swinglea with 50% alcohol is a better alternative. This extract is now being evaluated on farms around Madrid and Chía.

These experiments need to be continued at CIAT. Several products cause plant poisoning, which means the problem must be minimized, together with improving product preparation and application methods, and reducing dosage.

Lixiviation of compost with 50% fruits and vegetables for about 3 months affects sporulation in the fungus and disease incidence. A lixiviated fruit compost was obtained from Grajales S.A. (La Unión, Valle del Cauca). We plan to evaluate this potential biofungicide in experiments at Madrid and Chía.

Laurel, hairy beggar-ticks, and French marigold did not show control over powdery mildew, compared with Rubigan® **(Table 6.5)**. Possibly, fermenting these plants in water for several days will improve their efficiency.

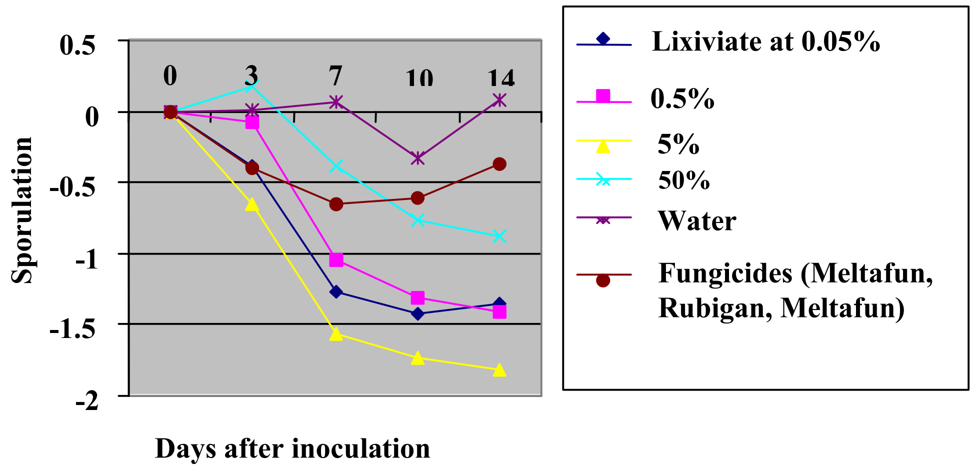

Figure 6.1. **Evaluating the treatment with lixiviated plantain compost for controlling powdery mildew in cultivar Livia under greenhouse conditions at CIAT, Palmira. Every 4 days plants were treated with four different concentrations. A chemical treatment was included as positive control. Nine plants per treatment were used. Sporulation was determined each four days using a range between 0 to 3 where 0 is no sporulation and 3 sporulated.**

Table 6.5. **First evaluation of plant extracts of swinglea, hairy beggar-ticks (*Bidens pilosa*), and French marigold (*Tagetes patula*) in controlling powdery mildew in rose cultivar Livia under greenhouse conditions at CIAT (experiment 5), Palmira. For the experiment, an average of two infected plants and two healthy plants were used, together with a chemical treatment as positive control.**

Treatment[a]	Development of Affected Leaves (%)	Development of Sporulation (%)
Hairy beggar-ticks	203	196
French marigold	108	108
Swinglea	91	163
Water	133	243
Rubigan	90	98

[a] The vegetal extracts were fermented during six hours en 50% ethanol.

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Activity 7. Evaluation of fungicides to control bud rot disease of oil palm in Meta and Cundinamarca

A trial to control bud rot in oil palm was conducted in a field of Unipalma, Paratebueno (Cundinamarca). Two and a half year old palms, genotype CIRAD C1001 F, were treated with two experimental fungicides used to control the fungi *Phytophthora* spp. in coconut palm, cocoa, and avocado in Australia. The product, coded as H, was used at 25% and 40%, and the product coded as NF was used at 100% in two ways—by injection into the trunk just under the bud, and by root absorption. Of each solution, 20 cm^3 were injected 15 cm deep into the trunk with a plastic injector. Root absorption was done by cutting two roots 1.4 m from the palm and immersing them in a plastic bag with 10 cm^3 of solution for each root. Healthy palms were also treated and a control with water was used.

The treatments reduced disease progress, although it continued increasing slowly. Solution H at 40% and NF were the best treatments for reducing disease progress, 5.5 months after application. The trunk, under the bud, was the best tissue into which to apply the solutions, although there were no significant differences with root absorption. The NF product reduced disease 2.5 and 3.5 months after treatment, although disease increased again, probably because of long application frequence period and rain favoring disease (**Figure 7.1.**).

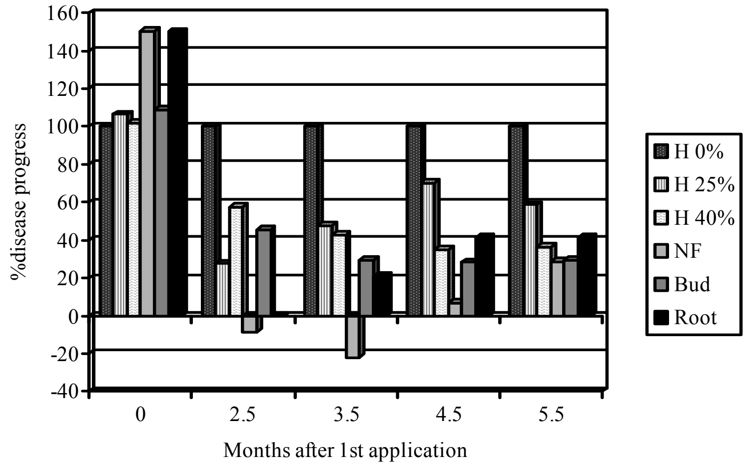

Figure 7.1. **Bud rot control in oil palm by injection under bud and root absorption, at a field in the eastern plains of Colombia.**

Activity 8. Participatory disease and crop management in the Colombian northeast Amazon

Ash (200 g per plant), organic matter (200 g per plant) from dead leaves taken from forest soil, and a mixture of both at a 1:1 ratio were evaluated by farmer participatory research methodologies for their effects on the yield of four native cassava varieties. Cassava was grown in *chagras*, which are small plots of slash-and-burn agriculture in rain forest. Farmers were women from four Tukano indigenous communities at Mitú (Vaupés). When ash was incorporated into the soil, the vigor scale was good (2.02 for yellow and 2.15 for white varieties), compared with traditional management (3.08 for yellow and 3.38 for white varieties). Incorporating organic matter gave yellow varieties 2.65 in the vigor scale and white varieties 2.38. Cutting selection without amendments had superior behavior to traditional management (**Table 8.1.**).

In Cucura community, the assay showed better yield with ash alone, then mixed with organic matter, and then using cutting selection. Root rot percentage was lower when ash is incorporated in the soil. Traditional management, without ammendments or cutting selection, had the lowest root yield and higher root rot. Other *chagras* will be harvested in November (**Table 8.2.**).

Table 8.1. Effect of organic matter (from dead leaves collected from forest soil), ash, and cutting selection on cassava vigor in four indigenous communities.

Treatment	Variety	Community				Average
		Seima Cachivera	Seima Central	Cucura	Puerto Palomas	
Ash	Yellow	1.0	2.5	3.3	1.3	2.02
Organic matter	Yellow	3.0	2.3	4.0	1.3	2.65
Ash + organic matter	Yellow	1.5	2.2	3.5	1.0	2.05
Cutting selection	Yellow	4.0	2.7	3.8	1.7	3.05
Traditional management	Yellow	4.0	2.5	4.5	1.3	3.08
Ash	White	2.0	2.5	2.8	1.3	2.15
Organic matter	White	1.5	3.2	2.8	2.0	2.38
Ash + organic matter	White	2.5	2.3	3.3	1.7	2.45
Cutting selection	White	4.0	3.5	3.3	2.0	3.20
Traditional management	White	4.0	4.0	3.8	1.7	3.38

[a] On a vigor scale where 1 = good and 5 = poor.

[b] Varieties: Seima Central: Yellow, Wasaí; White, Patabá. Pto. Palomas : Yellow, Yuca de Piña; White, Yuca de Rana. Seima Cachivera: Yellow, Yuca de Mico; White, Ibacabá. Cucura: Santa Catalina (low cyanide).

Table 8.2. Effect of organic matter (from dead leaves collected from forest soil), ash, and cutting selection on cassava yield and root rot percentage in Cucura, indigenous community, Mitú, Vaupés, Colombia.

Treatment	Cuttings/Plant	Yield (Kg/ha.)	Root Rot (Kg/ha.)	% Root Rot
Ash	5.4	5117	29.8	1.4
Organic matter	4.3	2943	37.2	8.3
Ash + organic matter	5.6	7497	0.0	0.0
Cutting selection	8.4	6405	206.6	2.5
Traditional management	0.9	1373	398.9	24.2

Four applications of 250 g per plant of the same treatments and chemical fertilizers (Di-ammonium phosphate at 4 g per plant and potassium chloride at 4 g per plant) were made, one per month, to evaluate the control of *Phytophthora capsici* under greenhouse conditions at CIAT, inoculating young stems of M Bra 12 by the wounding method. Plants were planted in 28-kg pots containing soil from Mitú.

Disease decreased when organic matter and chemical fertilizer were incorporated into the soil, while higher dry matter production was obtained by incorporation of a 1:1 mix of ash and organic matter (**Table 8.3.**).

Table 8.3. Effect of organic matter from dead leaves, collected from forest soil and ash, on the dry matter yield of the cassava variety M Bra 12 growing in a soil from Mitú (Vaupés, Colombia), and on the severity of *Phytophthora* rot in young stems in the greenhouse.

Treatment	AUDPC[1] (Inoculation 45 Days after Planting)	AUDPC[1] (Inoculation 90 Days after Planting)	Dry Matter (gr) 3 Months after Planting	Dry Matter (gr) 9 Months after Planting
Ash	8450	18182	26.46	97.5
Organic matter	3188	14361	26.43	90
Ash + organic matter	6267	21813	28.01	120
Chemical fertilizer	2158	12870	21.95	100
Control	4421	17397	23.37	105
No Inoculated	0	0	-	-
Duncan 5%	6795	7011	7.1	39.3

[1] AUDPC: Area under disease progress control

Activity 9. Paper submitted to Acta Agronómica Journal from the Universidad Nacional de Colombia, Palmira

Adaptation assessment of cassava varieties with resistance to Phytophthora spp., by participatory research at indigenous communities from Mitú (Vaupés, Colombia)

Elizabeth Alvarez, Germán Alberto Llano, John Loke, Raúl Madriñán, Jaime Andrés Restrepo, Jairo René Mora.

Cassava is a staple of the Amazon indigenous diet, and the marketing of its derived products provides a source of income. Because of land pressure around Mitú (Department of Vaupés, southeastern Colombia), shifting cultivation is no longer practiced with rotations, which had permitted forest regeneration, nor are plots adequately selected. One consequence is an increased incidence of cassava pests and diseases. Root rots, caused by several *Phytophthora* species, comprise a major production constraint in the region. Through surveys and meetings with communities, a crop management diagnostic was made and its relationships with root-rot incidence determined. Two thirds of the indigenous women farmers agreed that rots constituted the main cassava-production problem. The farmers were willing to try new varieties, describing the characteristics that they preferred. Based on the diagnostic, the researchers offered to indigenous to evaluate varieties with rot tolerance. Activities planning and evaluations were made with active communities participation and women diffused results. The indigenous helped the researchers to choose four *chagras* (farming plots), each from a different community. The farmers evaluated ten CIAT materials and nine local landraces according to their own selection criteria for the vegetative stage: vigor, plant health, plant height, stems per plant, and days to maturity. At harvest, the farmers also had specific criteria for adequate yield, starch content, and planting materials (stakes). The identified criteria led to a field book for evaluating cassava varieties in the zone. The farmers preferred the CIAT material CM 2772-3 (sweet, with yellow pulp) to the local landraces. Results were diffused, with farmers' participation, through meetings with the Department's Institutional Group, nongovernmental organizations, and communities.

Two field days were also conducted, and two pictographic handbooks published.

Activity 10. Evaluation of liquid compost from different sources as fertilizer in cassava

Foliar aspersion (20%) and soil application (50%) of liquid compost, twice weekly, were evaluated on cassava growth as fertilizer effect. Compost sources were plantain, fruit and vegetable, and organic matter processed by earthworms. Water was applied as control.

Plant height was measured every 2 weeks and foliar chemical analyses were made 1.5 months after the first treatment. Plants with foliar treatment were taller than with fertilized soil. The tallest plants were those with fruit and vegetable application. Plantain liquid compost had better performance in soil applications.

Mineral content in young leaves from plants treated with fruit and vegetable compost was higher than with other composts, showing high content of K, enough P, Ca, and Mg, and low N and S, according to CIAT **(Figure 10.1.)**. However, mineral contents obtained by foliar aspersion of fruit and vegetable compost were higher than in the control. With this product applied to the soil, P, K, Ca, and Mg were higher in leaves, than in the control.

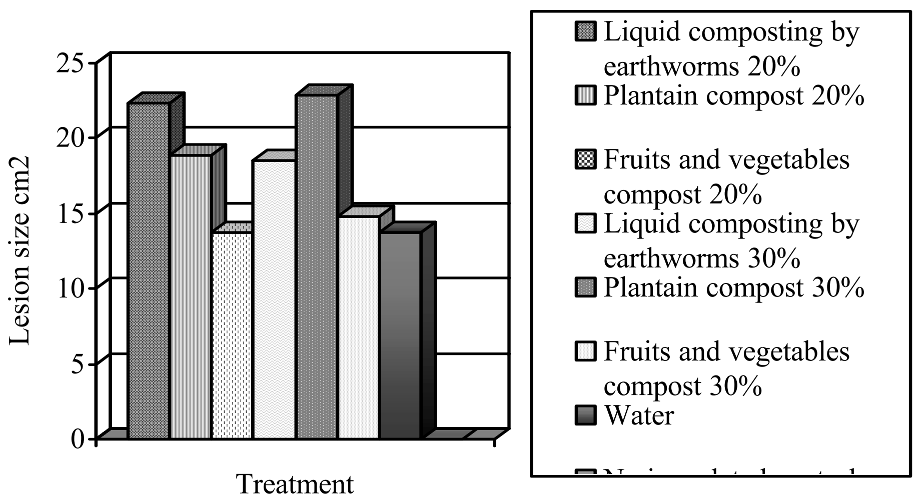

Figure 10.1. Mineral analyses of leaves (% dry matter) in cassava plants treated with different liquid compost sources.

The same treatments described above were applied to the genotype M Col 1505, susceptible to CBB, in order to evaluate the effect of liquid compost on *Xanthomonas axonopodis* pv. *manihotis*. The bacteria affected all inoculated plants, although those treated with fruit and vegetable compost were less affected by disease (**Figure 10.2.**), and its progress was lower than with other liquid compost sources.

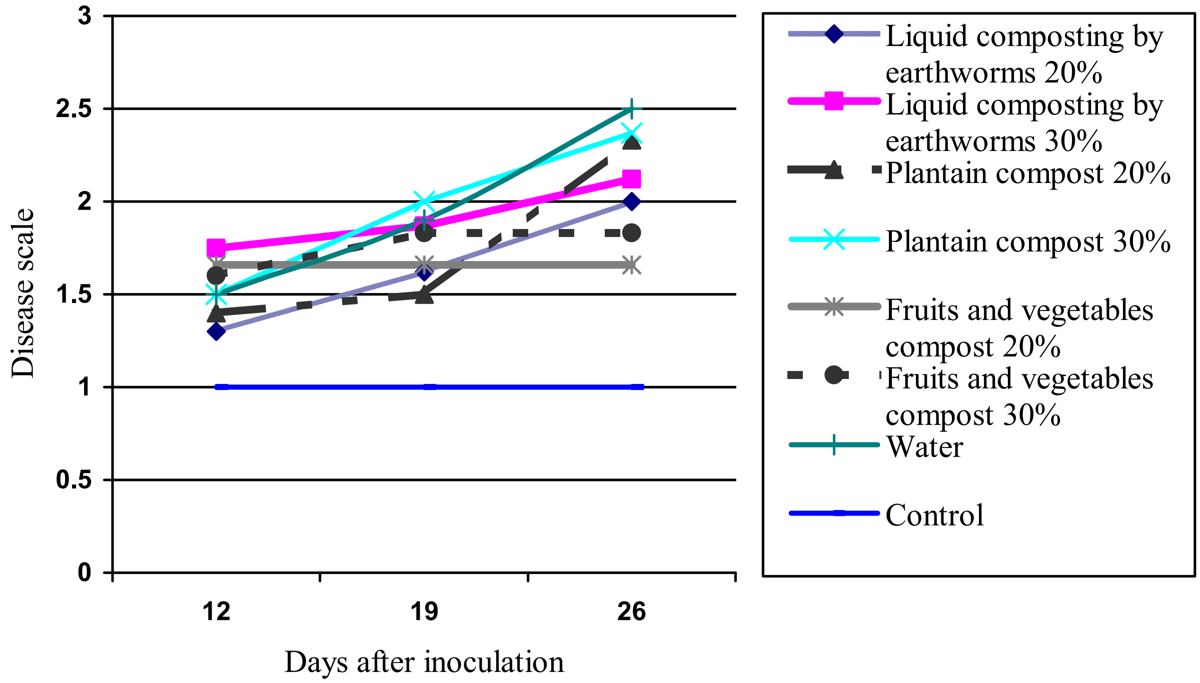

Figure10.2. Effect of different liquid compost sources on *Xanthomonas axonopodis* pv. *manihotis* control in cassava, variety M Col 1505.

Activity 11. Evaluation of liquid compost from different sources as fertilizer in cassava

Foliar aspersion (20%) and soil application (50%) of liquid compost, two times a week, were evaluated on cassava growth, as fertilizer effect. Compost sources were plantain, fruits + vegetables and organic matter processed by earthworms. Water was applied as control.

Plant height was measured each 2 weeks and foliar chemical analyses were done 1.5 months after first treatment. Plants with foliar treatment were higher than soil fertilized. The highest plants were those with fruits + vegetables application. Plantain liquid compost had better performance in soil applications.

Mineral content in young leaves from plants treated with fruits + vegetables compost were higher than other composts, showing high content of K, enough of P, Ca and Mg and low of N and S, according to CIAT (**Table 11.1**). Although, mineral contents obtained by foliar aspersion of fruit and vegetables compost were higher than control. With this product applied to soil, P, K, Ca and Mg were higher in leaves, than control.

Table 11.1. Leaves mineral analyses (% dry matter) in cassava plants treated with different liquid compost sources.

Sample	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
Foliar aspersion						
Control. Water to foliage	3,69	0,30	2,09	0,68	0,39	0,23
Plantain liquid compost 20%	3,41	0,24	2,13	0,68	0,37	0,25
Liquid compost from organic matter processed by earthworms, 20%	3,29	0,28	1,82	0,67	0,40	0,21
Fruits and vegetables liquid compost 20%	3,83	0,34	2,17	0,73	0,42	0,26
Soil application						
Control. Water to soil	3,35	0,23	2,12	0,65	0,37	0,22
Plantain liquid compost 50%	3,39	0,23	2,12	0,57	0,37	0,21
Liquid compost from organic matter processed by earthworms, 50%	3,01	0,24	2,11	0,59	0,35	0,21
Fruits and vegetables liquid compost 50%	3,07	0,26	2,22	0,69	70,41	0,20

Activity 12. Treatment of cassava cuttings with liquid compost

Cassava cuttings from varieties M COL 1505, M PER 183, and CM 523-7, immersed for 10 min in 35%, 50%, and 70% liquid compost from plantain and organic matter processed by earthworms, were planted in a field in Ginebra (Valle). They were compared with chemical treatment with Captan (1.5 gr L^{-1}), Benomyl (1.5 gr L^{-1}), and Dimetoato (1.2 cc L^{-1}). **Figure12.1.** shows the higher effects of chemical treatment, followed by organic matter from earthworms at 70% and 50%.

Applications were made every 15 days during the first 4 months, and 21 days later, to evaluate the effect on cassava plants' growth and yield. The trial is in progress.

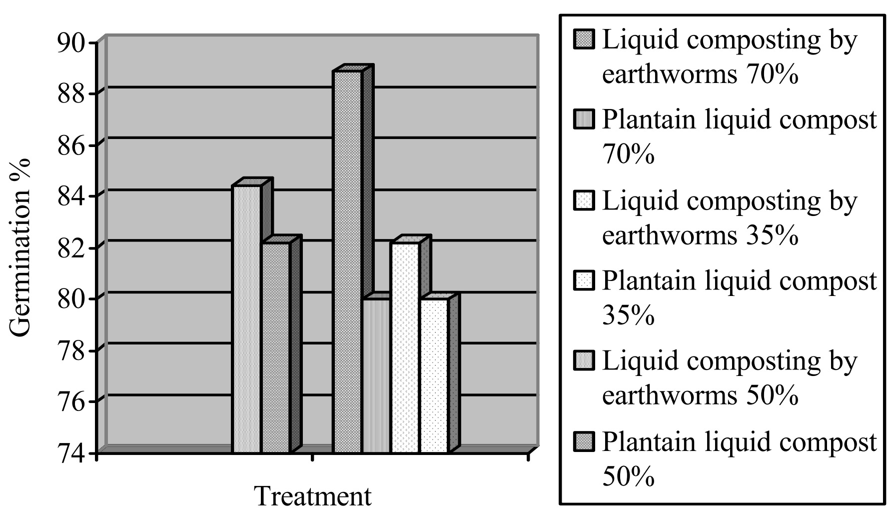

Figure 12.1. Effect on plant germination of treating cassava cuttings by immersion in different sources of liquid compost.

Publications

Handbook "Investigación Participativa para el control de pudriciones de yuca con comunidades indígenas de Mitú". 500 units.

"Evaluación de la adaptación de variedades de yuca con resistencia a *Phytophthora* spp., mediante investigación participativa en comunidades indígenas de Mitú (Vaupés, Colombia)". Acta Agronómica, journal from Universidad Nacional de Colombia, Sede Palmira. **In Press**.

Alvarez, E., J. L. Claroz, S. P. Cuero, and J. B. Loke. 2001. Controlling powdery mildew of roses using a plant extract and foliar fertilizers. Salt Lake 2001. APS, SON and MSA Joint Meeting August 25-29. Phytopathology 91:S101. Publication no. P-2001-0005-MSA.

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Sub-output 2. Developing IPM Strategies for Cassava Arthropod Pests.
(A. C. Bellotti)

Activity 1. The establishment of an IPM program for important cassava arthropod pests in Valle del Cauca and Cauca departments in Colombia

Introduction

The area under cassava production in Colombia is expanding due to the demand for cassava, not only as a human food, but more recently, its potential use as an animal feed. This increase in area, and in many cases, the increase in the size of cassava plantings, has led to an increase in arthropod pest problems. Populations and damage of the cassava hornworm, the cassava burrower bugs (C*yrtomenus bergi*), white grubs and whiteflies are increasing, and in certain cases, difficult to control.

Whitefly (*Aleurotrachelus socialis*) populations have increased dramatically in recent years and this is a very difficult pest to control. It has a short life cycle (about 1 months), a high rate of reproduction, considerable flight capacity, disseminating rapidly and its waxy, cerosine, covering on the nymphal and pupal stage can act as a protective devise against natural enemies and pesticide applications. In addition, changing planting patterns, especially in larger plantations, where cassava is planted more frequently, or "escalonada" presents optimal conditions for rapid population buildup. This is also aided considerably if cassava is irrigated (more young leaves produced, favorable to whitefly oviposition and nymphal development) or rains occur more frequently, shortening the dry season. Yield losses during severe attacks can reach 80%. These conditions prompt farmer reaction, usually the indiscriminate and ill-timed use of toxic pesticides.

This scenario has prompted the Colombian Ministry of Agriculture (MADR) to release funding co cope with this situation. A project has been designed to evaluate the options, or tools available to control whiteflies, there include the use of biopesticide, cultural practices, resistant varieties, biological control, trapping, and the rational or discriminate use of chemical pesticides.

The over-all goal is to develop an IPDM program for both small and large cassava farmers based on sound economical principles and is ecologically sustainable.

The specific objectives of the program are:

1. Determine optimal cassava pest management practices with cassava producers in Valle del Cauca and Cauca.
2. Identify selective chemical pesticides and biopesticides, determine doses and time of application for effective control with minimal effect on natural enemies.
3. Carry out field trials to recommend to cassava producers the use o effective natural enemies, including biopesticidas and parasitoids.
4. Train farmers in cassava IPM practices, emphasizing the reduction of pesticide applications and the use of natural enemies.

Materials and Methods

Visits were carried out with 46 cassava farmers in Valle del Cauca and Cauca. Surveys were done to identify current pest problems, present farmer pest control and crop management practices and farmer perceptions, needs and priorities. In addition, systematic sampling was done in farmers' fields to identify pest problems and design a general pest damage scale.

Chemical Pest Control

The cassava pest complex is associated with a larger number of natural enemies that play an important role in maintaining some pest populations below economic injury levels. For this reason, chemical pest control is considered a "last option," as indiscriminate pesticide use could reduce the effectiveness of natural or applied biological control. However the very high populations of whiteflies observed in farmers fields, is an indication that natural biological control is not effective or the most effective biocontrol agents are not present. This has forced farmers to apply chemical pesticides as an alternative to whitefly control. This is considered a short term alternative until effective biocontrol agents, especially entomopathogens, can be identified and resistant cassava varieties can be multiplied and made available to producers. Four experiments have been designed and are being carried out to determine effective pesticide practices and recommendations for whitefly control. Results that will be presented are preliminary as there are on-going experiments.

Experiment

1. Evaluations of chemical and biological pesticide for whitefly (*A. socialis*) control.

Preliminary experiments were carried out to design field methodologies for evaluation of the effectiveness of chemical pesticides. These were done at the farm "El Bohio" located in Santander de Quilichao (Cauca), 1000 m.a.s.l. with the cassava variety MBra 12. One month after planting foliar applications of 8 commercial products were made. These included Biomel (refined vegetable oils), Bioneem (neem extract), Bioterpeno (natural terpenoids), confidor (Imidacloprid), oportune (Buprofezin), tamaron (Metamidofos), sistemin (Dimethoate), and cipermetrina (generic). They were applied at the commercially recommended doses. The experimental design was completed randomized blocks, with 8 treatments, a control and four replications. Evaluations were initiated at the first sign of whiteflies, using a population scale, and after the first evaluation, evaluations were made every 15 days.

2. Evaluation of product efficiency in Santander de Quilichao and Jamundí.

In this experiment (Finca El Bohio) products with new or novel active ingredients are being evaluated for whitefly control, using the cassava variety "Parrita" (MCol 2758). The experimental design is completely randomized blocks with seven treatments, a control and four replications per treatment. The products tested include, Confidor (Imidacloprid), Oportune, Eltra (Carbosulfan), Actara (Tiametoxan), Polo (Diafentiuron), Epingle (Piriproxifen) and Citronela extract, all at commercially recommended doses. Product application and evaluations were made as cited in Experiment 1.

3. **Evaluation of imidacloprid (Confidor) efficiency for cassava whitefly (*A. socialis*) control.**

This experiment was carried out in "Agrovelez," an industrial size cassava plantation, in Jamundí, Valle del Cauca, with the cassava variety "Reina." Eight, doses are being tested as well as several different forms of application **(Table 1.1)**. The experimental design is completely randomized blocks with 7 treatments, one control, one commercial control and four repetitions per treatment. In preliminary trials, Confidor or Imidacloprid gave the best results for *A. socialis* control.

Table 1.1. Type and doses of imidacloprid application on cassava in field trials for *A. socialis* control.

Product		Doses/ha.	Type of application
Confidor SC 350	(Concentrated suspension)	0.6 lt.	Drench* at planting
Confidor SC 350	(Concentrated suspension)	0.8 lt.	Drench at planting
Confidor SC 350	(Concentrated suspension)	0.2 lt.	Drench at emerge
Gaucho FS 600	(Stake treatment)	0.4 lt.	Stake dip
Gaucho FS 600	(Stake treatment)	0.5 lt.	Stake dip
Confidor WG 70	(Granular treatment)	0.3 kg.	Drench at planting
Confidor WG 70	(Granular treatment)	0.4 kg.	Drench at planting
Imidor	(Commercial control)	0.2 lt.	Drench at emerge
Absolute control			

* Application to the base of the plant.

4. **Evaluation of Imidacloprid, Tiametoxan and Carbosulfan for *A. socialis* control in the greenhouse.**

In this experiment, carried out under greenhouse conditions several new products, including Actara (Tiametoxan) and Eltra (Carbosulfan) were compared to Imidacloprid for *A. socialis* control, using a completely aleatory design, with three treatments and an absolute control. Cassava leaves were immersed in the pesticide solution (commercial doses), and whitefly adults were released into leaf snap-cages. Mortality was evaluated after 48 hours. Experiments with higher than 10% mortality in the controls were discarded.

Results

Cassava Producers; Survey Results

This survey shows that cassava producers in the area surveyed do not employ a uniform criteria in cassava crop management **(Table 1.2)**. As can be seen numerous varieties and fertilizers are used within the same zone. Some varieties, such as chiroza, a very consumer popular eating variety with good fresh market value is grown throughout all the municipalities. Several types of fertilizers are applied and there is no consensus as to rate, nor time of application. Several herbicides are used for weed control, including round-up, gramoxone, karmex and estelar, as well as hand weeding or cultural practices, and there is considerable variation in doses and time of application.

Sixty Eight percent of the farmers surveyed indicated that they make their own decisions on crop management, with little or no outside technical advise. Those farmers with better economic resources, often do rely on technical assistance provided by consultants (agricultural engineers or technicians) (17%). In addition they also receive advise from agrochemical company representatives or commercial agrochemical outlets. NGO such as Fidar, Recampo and Cetec also provided technical assistance in 17% of the farms visited. CIAT has provided cassava-planting material. However 83% of the farmers surveyed have received no assistance from any organization.

Table 1.2. Cassava crop management characteristics from surveys of cassava producers in Cauca and North Valle del Cauca.

Department	Municipality	Variety	Fertilization	Weed Control	Advisors	Organization
Valle del	Alcalá	Chiroza	Lime	Round-up	Agriculturist	None
Cauca	Sevilla	Manzana	10-20-20	Gramoxone	Technician	Recampo
		Chiroza	15-15-15	Karmex	Agronomist	Cetec
	Caicedonia	HCM1	Urea	Estelar		Fidar
		Chiroza	KNO3	Cultural		CIAT
		Gallinaza	Microelements			
Cauca	S. Quilichao	523-7	DAP			
		Parrita	Cosmocel			
		Rancho Azul	Pdn. cassava			
		Verdecita	Kelatex -Zn			
		P12	KCl2			
		Algodona	Chicken manure			
	Buenos Aires	Verde	10-30-10			
		Barejona				
		Negrita				
		Roja				
		Venenosa				
		Blanquita				
		Verdecita				
	Caldono	Chiroza				
		J Jobio				
		Algodona				
		Roja				
		Varita				
		Chiroza				
		Batata				
		Raya Siete				
		P 12				

[1] 43 farmers surveyed.

Surveys of pest problems resulted in identifying nine arthropod pest species **(Figure 1.1)**. These include fruitflies (*Anastrepha* sp.), burrower bugs, hornworm, white grubs, leaf-cutter ants, thrips, shootflies (*Silba* sp.), mites and whiteflies. This is not surprising as the cassava crop is often accompanied by a diverse complex of arthropod pets. Their incidence and populations can vary from one zone to another. As can be observed **(Figures 1.1 and 1.2)** most pests are in low populations, indicting little or no economic importance. However populations of whiteflies in the North Cauca region were very high **(Figure 1.1)**, and probably causing yield losses.

A comparison between farm size and pest complex and populations indicates that cassava plantations of less than 10 ha. have a greater pest complex than larger plantations **(Figure 1.2)**. Whiteflies predominate on these smaller farms. This greater diversity if probably due to the fact that the smaller farms tend to be traditional cassava growers, planting cassava for numerous years, so pest species and populations have, over time, had the opportunity to establish. Larger farms are more recent plantings and pest problems have not yet established nor accumulated to higher populations. However, as can be observed **(Figure 1.2)**, whitefly populations are already high on these larger plantations, owing to the flight capacity or mobility, aided by wind currents, of whiteflies. These results confirm that some pests may become more problematic as plantation size increases.

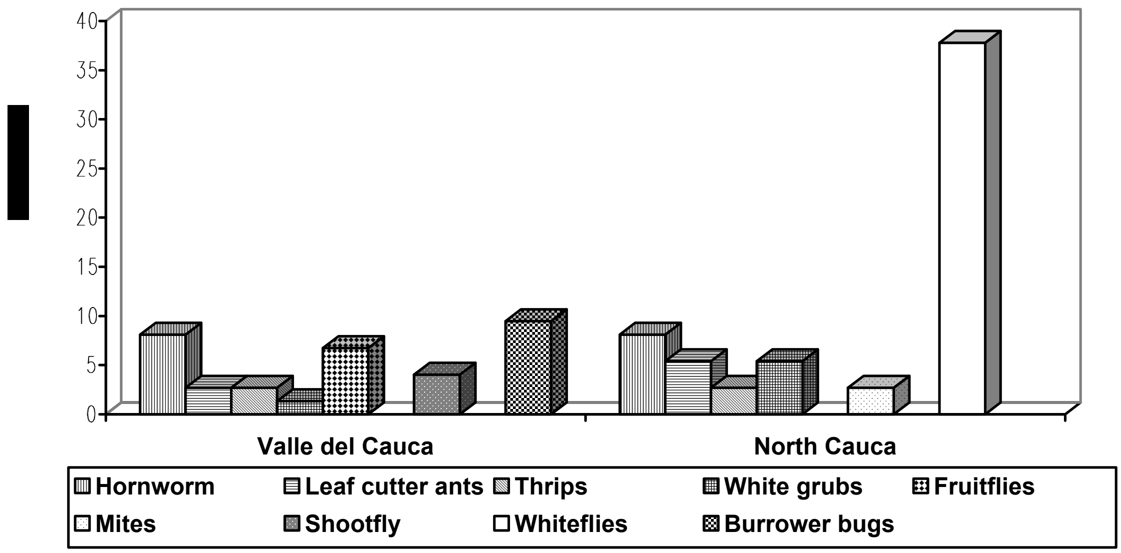

Figure 1.1. Cassava pest frequency from farm surveys in North Cauca and Valle del Cauca.

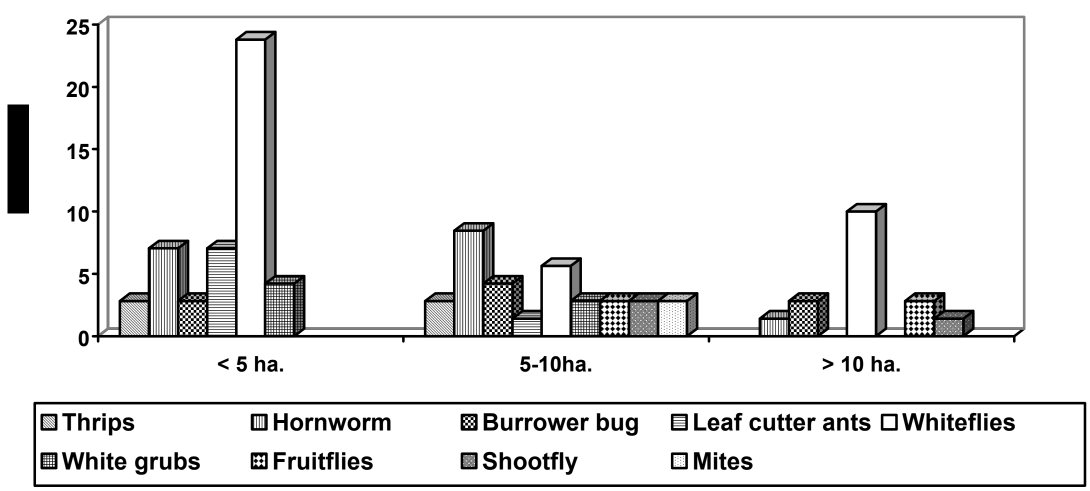

Figure 1.2. Cassava pest frequencies influenced by farm size in North Cauca and Valle del Cauca.

Evaluation of chemical and biological pesticides.

Results from the different biological and chemical pesticide evaluated for *A. socialis* control were similar **(Table 1.3)**. The biological products, biomel, bioneem and bioterpeno required additional applications (6 rather than 5 for other products). Only 3 applications of Imidacloprid (Confidor) were required to maintain low whitefly populations and this pesticide was the only treatment giving significantly different results **(Table 1.3)**. The other products did not present results significantly different from the control.

Table 1.3. The effect of different chemical and biological products on *Aleurotrachelus socialis* nymphs in the field.

Treatment	No. Applications	*A. socialis* Adult Population[3]			
		15 d.a.p.s*	45 d.a.p.s	75 d.a.p.s	105 d.a.p.s
Vegetable oils	6	1.91 ab[1]	3.42 ab	4.17 a	2.71 a
Neem	6	2.75 ab	3.62 ab	3.96 ab	2.62 a
Natural terpenoids	6	2.87 ab	3.54 ab	3.96 ab	2.48 ab
Imidacloprid	3	1.42 c***[2]	2.58 c***	3.42 b***	2.04 b ***
Buprofezin	5	2.25 b	2.96 ac	4.29a	2.48 ab
Metamidofos	5	3.21 a	4.00 a	4.37a	2.65 a
Dimetoato	5	1.92 ab	3.79 ab	4.04 a	2.71 a
Cipermetrina	5	2.33 ab	3.62 ab	4.12 a	2.50 ab
Control		3.12 ab	3.58 ab	4.37 a	2.92 a

[1] Duncan test, numbers followed by the same letter are not significantly different at the 5% level.
[2] Dunnett Comparison Test of treatments vs. control.
[3] Based on population scale; 1=no whiteflies present; 2=1-200 individual per cassava leaf; 3=201-500 per leaf; 4=501-2000 per leaf; 5=2001-4000 per leaf; 6=>4000 per leaf.
* d.a.p.s.: Days after application

The effects of the different products on adult populations were not significantly different from the control (no application) **(Table 1.4)**. Buprofezin and Imidacloprid showed a significant difference in egg population from the control, but not between treatments.

These results show that it is difficult to control *A. socialis* with conventional biological and chemical pesticides. As indicated earlier this may be due to the cerosine covering of immature *A. socialis* stages, that may provide protection, rendering pesticide applications ineffective. Metamidofos (Tamaron) and Dimethoate (Systemin) were at one time effectively used to control *A. socialis*, but due to continued applications, *A. socials* may now be resistant to these pesticides. Many of the products have been continually used for a considerable number of years to control whiteflies and may now be losing their effectiveness.

The methodology employed in this experiment permitted better knowledge of whitefly behavior over time, and was used in subsequent experiments.

Table 1.4. **The effect of applications of several pesticides on *A. socialis* egg and nymph survival in field trials.**

Treatment	No. Applications	Eggs	Adults[3]
Vegetable oils	6	3.60 ab[1]	3.28 ab
Neem	6	3.47 ab	3.17 ab
Natural Terpenoides	6	3.55 ab	3.32 ab
Imidacloprid	3	3.38 b	3.23 ab
Buprofezin	5	3.44 b***[2]	3.10 ab
Metamidofos	5	3.63 ab	3.46 a
Dimetoato	5	3.55 ab	3.23 ab
Cipermetrina	5	3.69 ab	3.28 ab
Control		3.83 a	3.48 a

1 Duncan test, numbers followed by the same letter are not statistically different at the 5% levels using DMS tests.
2 Dunnett test; comparison of treatments with control.
3 Based on population scale; 1=no whiteflies present; 2=1-200 individual per cassava leaf; 3=201-500 per leaf; 4=501-2000 per leaf; 5=2001-4000 per leaf; 6=>4000 per leaf.

Evaluations of chemical and biological products for whitefly control in Santander de Quilichao.

Results from this experiment show that tiametoxan gave the most effective control of *A. socialis* adults. All other products gave results not significantly different from the control **(Table 1.5)**. The best treatment for reducing egg populations was imidacloprid, when compared to the other products but did not differ significantly from the control **(Table 1.5)**.

The effects of these products on Nymphal populations indicate that several, including piriproxifen, tiametoxan and imidacloprid, gave results significantly different from the control **(Table 1.5)**. Citronela, the only biological pesticide evaluated in this trial, did not provide significant differences from the control **(Table 1.5)**.

Table 1.5. **The effect of foliar applications of biological and chemical pesticides on *A. socialis* eggs, nymphs and adults in Santander de Quilichao, Cauca.**

Treatment	Adults	Eggs	Nymphs[3]
Imidacloprid	1.81 abc[1]	1.96 c**	1.51 d**
Buprofezin	1.89 a	2.08 ab	1.88 ab
Carbosulfan	1.87 ab	2.06 abc	1.78 bc
Tiametoxan	1.78 c **[2]	1.97 c	1.56 d**
Diafentiuron	1.82 abc	2.07 ab	1.87 ab
Piriproxifen	1.80 bc	2.04 abc	1.70 c*
Citronela	1.87 ab	2.12 a	1.91 a
Control	1.86 ab	2.01 ac	1.99 a

1 Duncan test, numbers followed by the same letter are not statistically different at the 5% levels using DMS tests.
2 Differences highly significant.
3 Based on population scale; 1=no whiteflies present; 2=1-200 individual per cassava leaf; 3=201-500 per leaf; 4=501-2000 per leaf; 5=2001-4000 per leaf; 6=>4000 per leaf.

Evaluation of chemical pesticide for *A. socialis* control in Jamundí (Valle del Cauca).

Results from this experiment show that only tiametoxan and carbosulfan gave results significantly different from the control for adult *A. socialis* control **(Table 1.6)**. For eggs, imidacloprid was the only treatment that presented significant differences. For nymphs, all treatments were significantly different from the control, with tiametoxan giving the best results, followed by imidacloprid.

Tiametoxan gave the best results over the two experimental sites, Santander de Quilichao and Jamundí, especially for adult and nymph control. Imidacloprid gave the next best results.

Table 1.6. The effect of foliar applications of chemical and biological products on *A. socialis* eggs, nymphs and adults in Jamundí, Valle del Cauca.

Treatment	Adults	Eggs	Nymphs[3]
Imidacloprid	1.55 ab	1.61 abc	1.45 c*
Buprofezin	1.51 bc	1.65 a	1.53 b
Carbosulfan	1.49 c**	1.61 abc	1.54 b
Tiametoxan	1.48 c**	1.59 abc	1.30 e**
Diafentiuron	1.51 bc	1.54 bc	1.41 dc
Piriproxifen	1.58 a	1.65 a	1.54 b
Imidacloprid (2)	1.50 bc	1.52 c**	1.35 de
Control	1.55 ab	1.62 ab	1.61 a

1 Duncan test, numbers followed by the same letter are not statistically different at the 5% levels using DMS tests.
2 Differences highly significant.
3 Based on population scale; 1=no whiteflies present; 2=1-200 individual per cassava leaf; 3=201-500 per leaf; 4=501-2000 per leaf; 5=2001-4000 per leaf; 6=>4000 per leaf.

Evaluation of Imidacloprid for *A. socialis* control in cassava in Jamundí.

Confidor (Imidacloprid) was applied in three forms, a suspension, stake treatment, and as a granular.

All treatments gave results significantly different from the control for adult control of *A. socialis* **(Table 1.7)**. The drench treatment with a concentrated suspension or stake treatment gave the best results but not significantly different from the other treatments.

The best treatment for reducing egg populations was applying imidacloprid as a drench, concentrated suspension at the time of planting. (0.6 lt./ha).

Nymphal results were similar as those for adults in that all treatments differed significantly from the control. Imidacloprid applied at the time of plating in concentrated suspension in drench from gave the best results (0.6 a d0.8 lt./ha).

Results show that a drench application at the time of planting, using a concentrated suspension at a doses of 0.6 or 0.8 lt./ha. Gives the best control of *A. socialis*.

Table 1.7. The effect different treatments and doses of the pesticide imidacloprid (Confidor) on *A. socialis* eggs, nymphs, and adults in Jamundí (Valle del Cauca).

Treatment	Adults	Eggs	Nymphs[3]
Confidor SC 350 (Concentrated	1.52 b**	1.47 e**	1.44 c**
suspension)	1.55 b	1.55 d**	1.32 d**
Confidor SC 350 (Concentrated	1.58 b	1.59 dc	1.45 bc
suspension)	1.52 b	1.65 bc	1.55 b
Confidor SC 350 (Concentrated	1.59 b	1.68 abc	1.51 bc
suspension)	1.58 b	1.68 abc	1.48 bc
Gaucho FS 600 (Stake treatment)	1.55 b	1.65 bc	1.52 bc
Gaucho FS 600 (Stake treatment)	1.57 b	1.72 ab	1.52 bc
Confidor WG 70 (Granular application)	1.67 a	1.75 a	1.78 a
Confidor WG 70 (Granular application)			
Imidor (Commercial control)			
Absolute control			

1 Duncan test, numbers followed by the same letter are not statistically different at the 5% levels using DMS tests.
2 Differences highly significant.
3 Based on population scale; 1=no whiteflies present; 2=1-200 individual per cassava leaf; 3=201-500 per leaf; 4=501-2000 per leaf; 5=2001-4000 per leaf; 6=>4000 per leaf.

Evaluation of imidacloprid, tiametoxan and carbosulfan for whitefly control in the greenhouse.

These results indicate that greenhouse testing gives optimal results of *A. socialis* control. All treatments gave significantly different results from the control and all products resulted in whitefly mortalities over 73% **(Table 1.8)**. These results support finding from field trials. The three products, imidacloprid, tiametoxan and carbosulfan also gave the best control in field trials. These results also indicate that those methodologies employed for greenhouse testing of products are reliable for field extrapolation.

Table 1.8. Percent mortality of *A. socialis* adults after applications of three chemical pesticides in the greenhouse.

Treatment	Experiment 1	Experiment 2	Experiment 3	Combined Experiment
Imidacloprid	84***[1]	73.75***	87.5***	83.23***
Tiametoxan	84***	73.75***	85***	82.52***
Carbosulfan	84***	73.75***	84.5***	82.23***
Control				

1 Dunnett comparison test of treatments with control.

Conclusions

The survey of cassava producers has provided considerable information and is an aid in executing this project as it allowed us to know the needs and priorities of cassava farmers. It also provided important information on farmer crop management practices.

In addition the survey provided important information on the cassava pest complex, identifying whiteflies, *A. socialis*, as the most important pest in the complex. The differences indicated between small (<10ha) and large (>10ha) plantations, although important at present, need to be observed over time, and needs to be compared to cultural practices, especially planting dates and patterns, varietal mixtures and pesticides used, particularly on the larger plantations.

Preliminary results with biological and chemical pesticides indicate that control of whiteflies will be difficult and may be costly. Only a few products were effective and the results of the biopesticide were/are disappointing. Confidor (Imidacloprid) was the only product that gave effective control of nymphs; nymphal control is essential for reducing whitefly populations. Tiametoxan also gave adequate control for nymphs.

Drench applications with a concentrated suspension at planting time at 0.6 to 0.8 lt./ha. Effectively reduced populations of eggs, nymphs and adult whiteflies (*A. socialis*).

Collaborators

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Sub-output 3. Disease Management Components and IPM Strategies and Tactic developed for Bean Root Rots in Africa.
(R. Buruchara)

Activity 1. Indigenous knowledge, perceptions and traditional management of bean root rots in southwest Uganda

Introduction

Bean root rots are associated with intensification in agriculture, declining soil fertility and in Eastern Africa association with bean stem maggot, making diagnosis difficulty. Research efforts have been made in characterizing the diseases, their causal agents, damage caused and in developing integrated management technologies that include varietal and cultural options. However, to develop dissemination strategies and increase the rate of technology uptake by small-holder farmers, there is need to first understand local knowledge, farmer perceptions of the diseases and their relative importance to other constraints, and traditional management strategies.

Materials and Methods

In-depth informal and formal surveys were carried out in two study sites in southwestern Uganda districts of Kabale and Kisoro where bean root rots (BRR) are a serious problem but where dissemination of management technologies had never been carried out. Informal surveys were designed to target "knowledgeable" farmers (35 in both study communities) and data collection procedures used included participant observation, key informant and group interviews, informal discussions and field observations conducted over the growing period of the crop (three months). The formal survey based on a structured questionnaire was carried on 100 farmers.

Results and Discussion

The local names for root rots in the study areas (Kabale and Kisoro) are *Kiniga* and *Churisuka* respectively. Literally *Kiniga* means, "is angry and commits suicide" while *Churisuka* means "coming home with only a hoe and no harvest". The names depict the effect of the disease on beans and its importance, assessed on the basis of the effects on the crop. Generally, damage to beans (due to diseases) is categorized into "soil and rain diseases". BRR is considered a soil disease because of rotting of roots while foliar diseases are regarded as "rain diseases" because of their association with rain.

Disease Recognition**:** Most farmers (94 %) recognize and clearly describe above-the-ground symptoms of BRR (yellowing), while a lesser but significant number (64%) associate rotting of roots with BRR. A few think above-the-ground (yellowing) and below-the-ground (rots) symptoms are two distinct and unrelated problems. Development and appearance of symptoms is a well-understood process and 85% observe symptoms at the 2nd and 3rd leaf stage. However, symptoms and effects of root rots and bean stem maggot (BSM) are largely undistinguished.

***Cause of Root Rots*:** Conditions associated or considered to cause BRR include poor soils, continuous cropping, use of poor seed, water stagnating in fields, too much rain or drought conditions. The latter further testifies the lack of distinction between the effects of BRR, BSM or even soil fertility. Too much rain implies heavy down pours resulting in high moisture content in the soil.

***Traditional Management Practices*:** The destructive effects of root rots were early on associated with bad omen by some communities, which used certain rituals to "chase it away" without success. Other traditional management practices that have been used are varietal changes and adjustment. Sixty percent of farmers have made changes to their traditional varieties. About 50% and 40% of farmers stopped growing large and medium sized seed respectively due to their susceptibility. Forty-eight percent introduced small sized seed because of their tolerance to root rots and high yields. Sixty percent adjusted components of varietal mixtures by either removing large seeded (36%), planting only medium and small seeded (17%), increasing small seed proportions within the mixture (16%) or simply reducing the proportions of big seed (14%).

A number of cultural practices are carried out routinely for reasons other than managing root rots. These include manuring (63%) to improve soil fertility, "seasonal rotation " (100%) to meet needs for other crops, fallowing (54%) in very poor plots to improve soil fertility, planting on raised beds or ridges (90% in Kisoro) to avoid flooding, growing beans as a sole crop particularly climbers (91%), intercropping (94%) and terracing (71%). Whereas some of these practices are useful IPM components (manuring or planting on raised beds) against root rots farmers do not appreciate them as such.

Conclusion and Implications: The above clearly show that:

- Farmers have a good knowledge of the above-the-ground symptoms and overall crop damage caused by BRR based on their observations
- Farmers associate the disease with certain soil and environmental factors. However, due to reliance on ("easily visible") symptoms (yellowing, wilting) effects of ("invisible") BSM and soil fertility are easily confused as being due to root rots. This is a major diagnostic weakness that can result in the use of wrong or rejection of appropriate management practices.
- Traditional management practices having useful effects have been limited to varietal manipulation leading to reduction or elimination of large and introduction of small seeded components in varietal mixtures.
- Certain practices (manuring, planting on mound or ridges) are routinely used for other reasons and are not appreciated as components in the IPM of root rots.

Results obtained clearly show the need for using a learning approach in introducing and dissemination of IPM technologies against root rots (and BSM) among the communities studied. However, the understanding of the farmer traditional knowledge of BRR gained should enable development of appropriate materials information to fill gaps in farmers' knowledge.

Contributors

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Sub-output 4. Make more Options Available for Managing Soil Productivity and Bean Pests.
(K. Ampofo)

Activity 1. Studies on *Ootheca* biology and development

Introduction

Farmers believed "*Ootheca* came with the rains and went with the rains", however, having realized that *Ootheca* developed in the soil within their own fields, they were eager to learn more about the biology and development in relation to their production circumstances. We encouraged farmers to sample soil for the appearance of the different stages of the pest in the learning plots. In addition we undertook a lab and screenhouse study to understand the details of *Ootheca* biology.

Materials and Methods

Mating pairs of *Ootheca* were collected from the field and caged with a petri dish of loose soil. They were monitored for oviposition and all eggs laid were collected, counted and incubated under ambient temperature conditions. Neonates were removed and placed in soil with a potted bean plant. There were 168 such pots. Each week 6 pots were removed randomly and sampled for larvae. Head capsule widths (HCW) of all larvae collected were measured. Frequency distribution of the HCW was plotted and the number of instars determined.

Results

The developmental parameters of *Ootheca* eggs and larvae are described in **Table 1.1**. Newly emerged females had a pre-oviposition period of 2 – 3 days and laid up to 564 eggs over about 3 weeks. The eggs took 2 – 3 weeks to hatch at ambient temperatures between 17 and 27 ^{o}C. Egg viability was 97.6%. There were three larval instars **(Figure 1.1)** with the larval stage lasting over 24 weeks from April until September. Mean head capsule widths of the different instars are presented in **Table 1.2**. Pupation started in September and early adults hatched in early October but remained in teneral diapause. These laboratory and screen house studies confirm field observations on *Ootheca* development but the lab studies shed more light on the biological parameters of the larvae

Table 1.1. Some developmental parameters of *Ootheca* in northern Tanzania.

Parameter	Mean $\pm$ SEM	Range
Pre-oviposition period	2.8 $\pm$ 0.34	2-3
Eggs laid /female	148 $\pm$ 107	20-564
Oviposition period	22 $\pm$ 13	3-52
Egg batch size	59 $\pm$ 5	53-67
Number of batches	4.5 $\pm$ 2.5	1-8
Incubation period (days)	16.9 $\pm$ 1.89	13-20
Incubation temperature (^{o}C)	20.8 $\pm$ 2.67	17-27

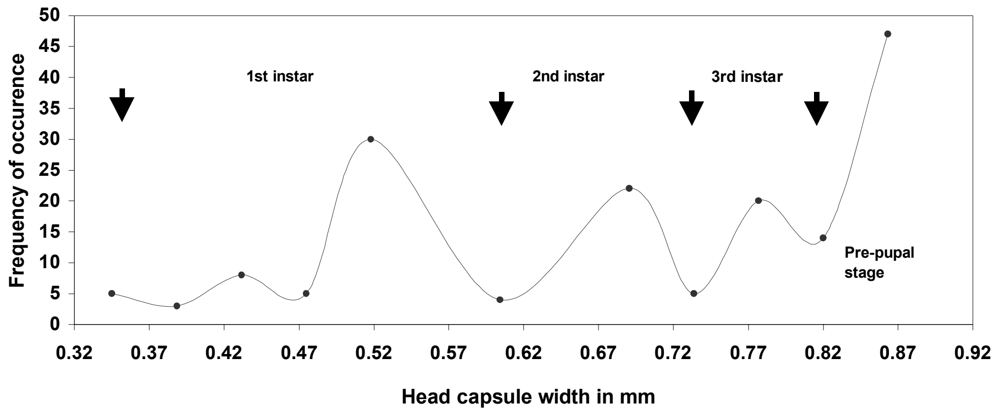

Figure 1.1. Frequency distribution of larval head capsule widths of *Ootheca.*

Table 1.2. Mean head capsule widths (mm) and duration of different larval instars of *Ootheca.*

Instar	Head Capsule Width		
	Mean ± SEM	**Range**	**Duration in Weeks**
First	0.485 ± 0.0664	0.345- 0.604	5
Second	0.695 ± 0.0244	0.604 – 0.734	8
Third	0.794 ± 0.0237	0.734 – 0.820	11

Activity 2. Understanding factors that influence bean stem maggot population dynamics

Introduction

BSM ecology is not well understood and this leads to difficulties in predicting population changes. This year we monitored BSM species population dynamics in relation to various climatic variables and the incidence of parasitism. The data could be used to develop models for advisory forecasting the pest's populations.

Materials and Methods

Beans were planted on weekly basis at Selian, Arusha (ca 3^0 S and 1380 m.a.s.l.). Plants were removed at 3 weeks after emergence and all insects extracted and sorted into species using puparial characters. Other plants from the same group on each sampling occasion were placed in a paper bag and sealed to determine adult or parasite emergence. Parasites are stored for later species determination.

Results

O. spencerella was dominant throughout the monitoring period **(Figure 2.1)**. There was always a decline in BSM populations to the lowest level during April each year, but populations were high in May to August. The population increases and decreases of the parasite population appear to follow the BSM population trends very closely. Rainfall (a) does not appear to be a major factor, even though low populations in April coincided with periods of high rainfall. These periods also coincide with the planting of beans in the Arusha area. Delayed planting often results in high BSM infestation.

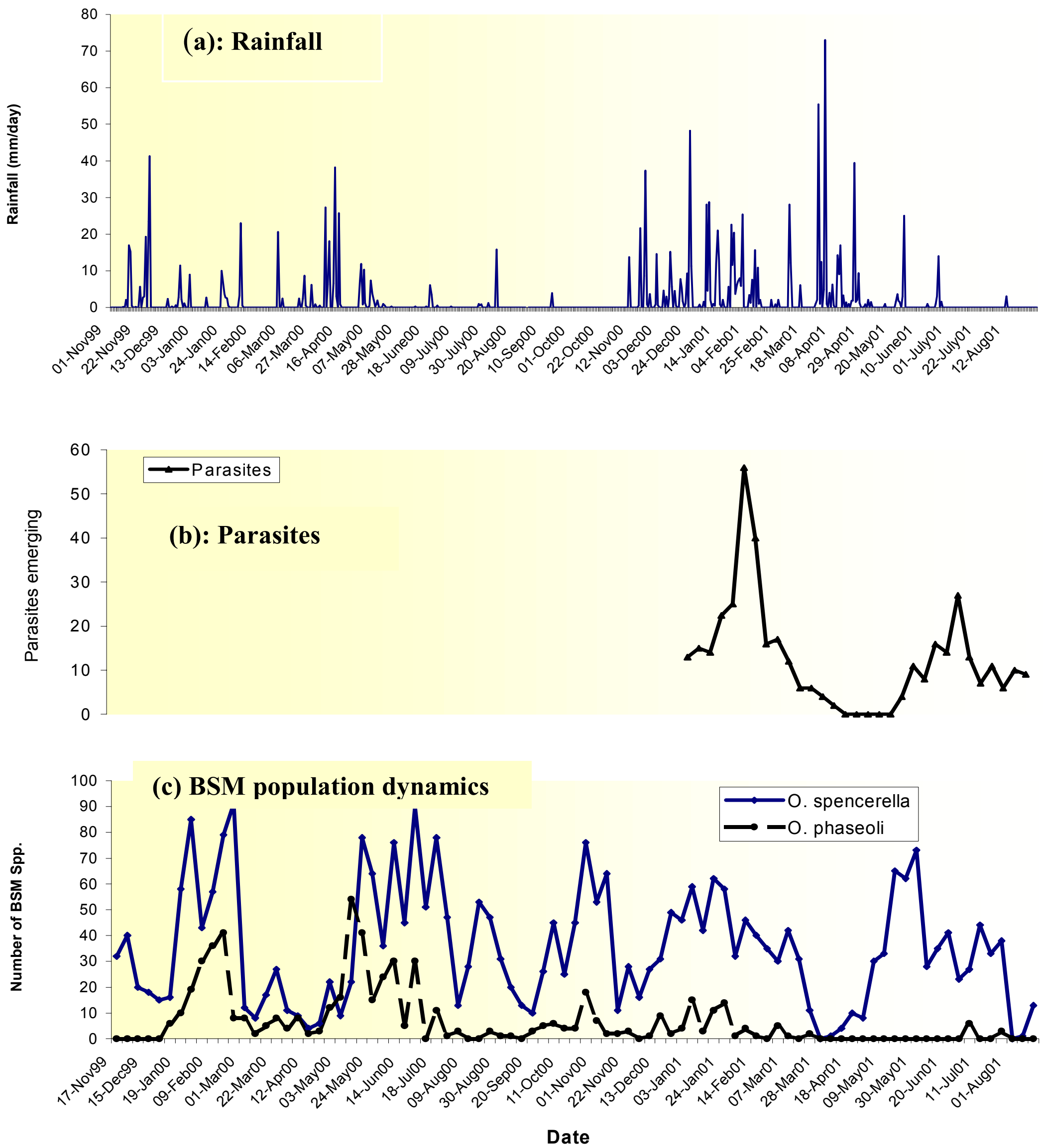

Figure 2.1. Relationship between rainfall patterns, the incidence of parasitism and BSM population dynamics in Arusha.

Activity 3. Relationship between pod damage characteristics, time of harvest and bruchid infestation

Introduction

Farmers experience high bruchid infestation in their harvested produce after a few weeks of storage. This forces them to sell their produce soon after harvest for low prices. They were unaware of bruchid infestation in the field.

Materials and Methods

A sequential harvest program was initiated with the community in Sanya Juu (N. Tanzania) to monitor the relationship between time of harvest and bruchid infestation. Beans were harvested at physiological maturity, and at two weekly intervals thereafter for 4 weeks. The harvested beans were grouped into split and intact clean pods and according to the number of holes (pod borer damage). The grains were extracted from the pods and stored in sealed paper bags for 8 weeks. The grains were then examined and all emerging insects were collected and recorded, grain damage was also recorded. The data were analyzed and discussed with farmers.

Results: Grains from pods that provided access for bruchid entry; pods with pod borer damage and split pods (as a result of delayed harvesting) were more attacked than intact pods **(Figure 3.1)**. Also pods harvested at physiological maturity had significantly less damage than later harvested pods. Grain damage increased progressively with weeks after physiological maturity **(Figure 3.2)**. Each week of delayed harvest resulted in 7 % grain infestation by Acanthoscelides obtectus.

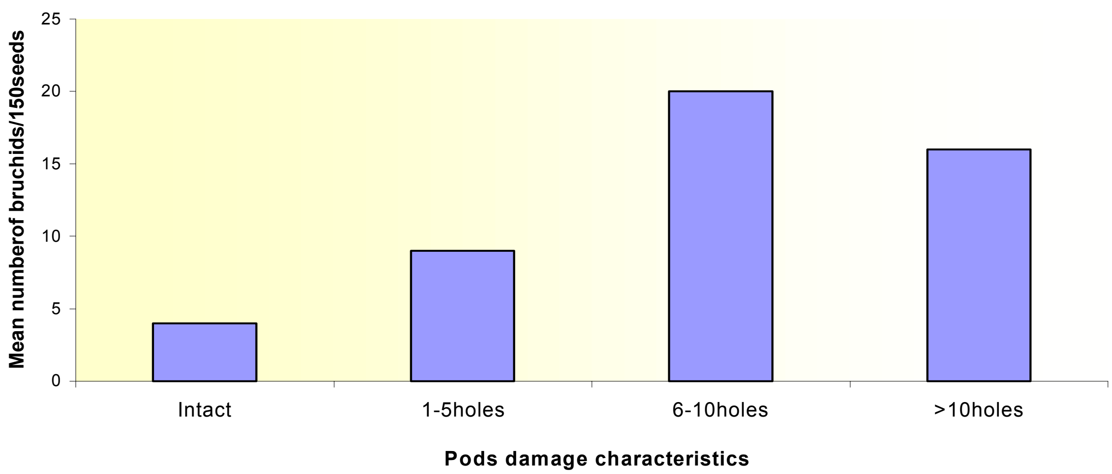

Figure 3.1. Pod damage characteristics at harvest and bruchid infestation.

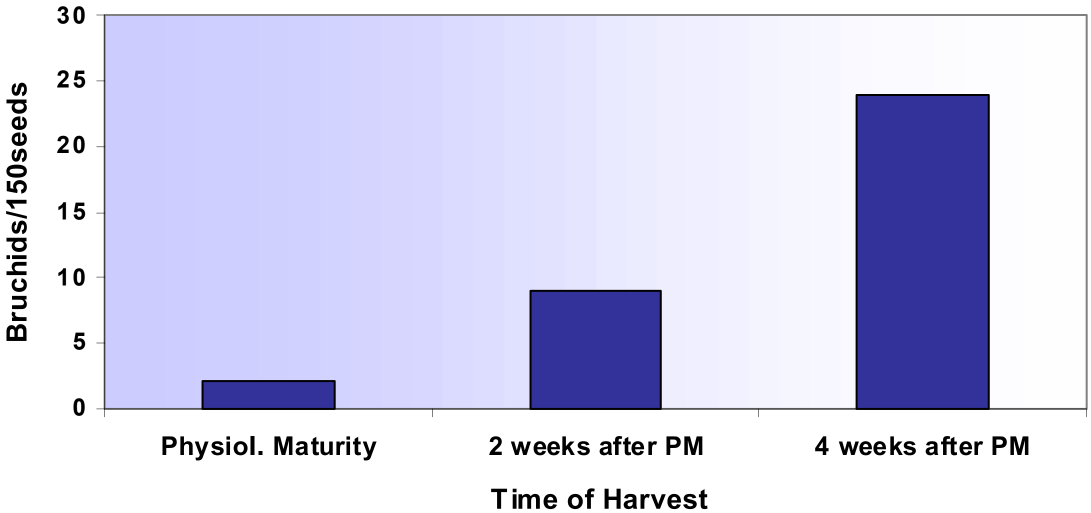

Figure 3.2. Relationship between time of harvest after physiological maturity and bruchid infestation.

Among the Wasambaa in Lushoto District of Northern Tanzania, farmers harvest soon after physiological maturity (early) as a tradition and sell their produce soon after harvest without much time in storage, either because they are aware of the high bruchid infestation associated with delayed harvest or that they sell wet seed to take advantage of the seed weight. The farmers' claim they gain more from the early harvest than if they harvest late. Grain harvested this way and air-dried was kept for 4 months without bruchid emergence. For longer term storage, farmers add dust or sun-dry or smoke the harvest and this protects the grain for much longer.

Collaborators

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