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Full Length Research Paper

Fungicide effect of banana column juice on tomato southern blight caused by *Sclerotium rolfsii*: Technical and economic efficiency

Rachidatou Sikirou[1]*, Afio Zannou[2], Gualbert Gbèhounou[1], Félicien Tosso[3] and Françoise Assogba Komlan[4]

[1]Laboratory of Crop Protection, Agricultural Research Centre of Agonkanmey, National Institute of Agricultural Research of Benin (INRAB), 01 BP 128 Porto-Novo, Republic of Benin.
[2]Department of Economics, Socio-Anthropology and Communication, Faculty of Agronomic Sciences, University of Abomey-Calavi, Benin, 01 BP 526 Cotonou, Republic of Benin.
[3]Laboratory of Applied Ecology, Faculty of Agronomic Sciences, University of Abomey-Calavi, Republic of Benin.
[4]Vegetable Crops Unit, Agricultural Research Centre/ erennial Crops of Pobé, National Institute of Agricultural Research of Benin (INRAB), 01 B.P. 988 Cotonou, Republic of Benin.

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The efficiency of banana column juice was compared to that of the synthetic fungicide Maneb 80 and urea in laboratory, in pots under shed and in the field. In laboratory, the products underwent trials conducted on the culture of *Sclerotium rolfsii,* in pots on artificially inoculated plants, and in the field on plants installed in a completely randomized block design with three repetitions on a naturally fungus infected field. The banana column juice, the urea and the Maneb 80 inhibited the growth of the mycelium and the germination of the sclerotia. The analysis of the variance of the Area Under Disease Incidence Progress Curve (AUIPC) showed a highly significant difference among treatments. In the control of the disease, the benefit of the treatment with banana column juice, Maneb 80 and urea resulted in the reduction of the incidence by 45.5, 31.6 and 38.2% respectively and an increase of the yield of about 27.5, 25.5 and 10.5% respectively. The banana column juice was technically more efficient than Maneb 80 and urea. The banana column juice and the Maneb 80 were economically profitable only during the off-season. The simultaneous application of banana column juice and urea was an amendment harmful to tomato growing.

Key words: Benin, disease control, biofungicide, *sclerotium rolfsii*, decision matrix, tomato, economic evaluation.

INTRODUCTION

Tomato is the key fruit vegetable in Benin and it represents an important food supplement for the Beninese population. In addition, it constitutes a significant source of income for producers, but its yield still remains very low due to the not yet controlled disastrous phytosanitary problems that confront it. Among the phytosanitary problems, tomato wilt caused by *Sclerotium rolfsii* is one of the most important. It is widespread in all tomato growing areas. It appears at any stage of the plant development and during all seasons and causes tremendous yield losses. In Benin, losses varied between 35 and 90% (Sikirou et al., 2001). In Morocco, the fungus has caused yield losses up to 50% on sugar cane and an incidence rate ranging from 60 to 80% on sunflower (Achbani and Tourvielle de Labrouhe, 2000). To control the fungus, a number of methods have been tested. Among others one can mention the cultural control based on crop rotation, solarisation and deep ploughing aimed reducing the *S. rolfsii* inoculum rate(Garen Knnet, 1991), biological control (Wokocha, 1990; Punja et al., 1982), the application of organic

*Corresponding author. E-mail : rachidatous@yahoo.fr. Tel. (229) 20212933.

amendments such as compost and manure (Toribio, 1989; Garen Knnet, 1991) and chemical control. Control of *S. rolfsii* has been obtained on several crops by fungicide applications, as foliar sprays, soil drenches or seed treatment. Successful control by spray applications has been reported for tebuconazole on groundnut (Grichar, 1995). Quintozene, chloroneb and tridemorph applied as soil drenches gave good control of sugarbeet infection in field plots inoculated with sclerotia of *S. rolfsii* (Sharma et al., 1990). Other effective soil drenches included carboxin on sweet potato (Sivaprakasam and Kandaswamy, 1983) and benodanil on wheat (Hagan et al., 1991).

The *S. rolfsii*, being soil born pathogen with broad range of host, and ubiquitous parasite (Aycock, 1966) was hard to be controlled by a simple cultural method. Crop rotation has a strong influence on the survival of *S. rolfsii*. Populations of viable sclerotia were highest in soil in a field in which tomatoes were planted for three successive years and in one in which tomatoes followed groundnut in two years while lowest sclerotial numbers were recorded in fields in which groundnut followed maize (Wokocha, 1988). But fallow of less than five years did not significantly reduce the inoculum of *S. rolfsii* in the soil (Sikirou et al., 2001). Tomato fields cultivated after 7 to 8 years fallowing have shown total absence of *S. rolfsii* symptoms (Sikirou et al., 2001). In view of the high demand for vegetables, especially in urban and peri-urban areas, very few tomato market gardeners or producers respect crop rotations. Chemical fungicides are expensive, unavailable and not often efficient against *S. rolfsii*. Biofungicides are often recommended as means to reduce diseases. To control *S. rolfsii*, very few biofungicides have been tested. Besides its nutritional properties, banana species have been reported to have various biological activities and pharmacological properties such as anti-ulcerogenic, anti-diabetic, anti-atherogenic, anti-diarrheic and anti-tumoral have also been found to be effective in treatment of migraine, hypertension and cholesterol (Orhan, 2001). Barre et al. (2000) demonstrated that Banana and its pseudo stem contain pathogenesis-proteins possessing antimicrobial properties. Matekaire et al. (2005) reported the mild effect of banana root on coccidios affecting voluntary feed intake, digestive and reproductive performance of modern rabbit. According to Best et al. (1984) the unripe plantain banana fruit has an anti-ulcerogenic activity. Also Lewis et al. (1999) working on unripe plantain banana pulp (*Musa sapientum* L. var. *parasidiaca*) reported that the extracted leucocyanidin and a purified synthetic leucocyanidin had similar protective effect against aspirin-induced erosions. Sap of banana leaves and trunk are used against abscess, bacterial infections, boils, chronic sores, mild diarrhea and skin ulcerations (David Bruce Leonard, 2006). Its young leaves heated extract is efficient against eye infection (Milliken and Albert, 1996). In the present study, the fungicide effect of banana column juice on the development of southern blight caused by *S. rolfsii* and its economic profitability were investigated in the south of Benin.

MATERIALS AND METHODS

Laboratory tests

Extraction of banana column juice

1. Extraction by mill: Banana bunch rachises, that is, banana columns, were cleaned with ethanol (70%), and then cut into small pieces of about 1cm^3. The pieces were deposited in a mill (maximum power of 400 W). When the appliance starts up, the juice was collected.
2. Extraction in the traditional way: After being cleaned with ethanol (70%), rachises were cut into larger pieces (3 to 4 cm^3), then deposited in a traditional mortar previously cleaned with ethanol (70%). The pestle was also washed with water and cleaned with ethanol (70%). After 20 to 30 min of pounding, the pounded mass was then poured in a bowl and hand-pressed in another. The juice so collected was filtered with a sieve of 1 mm mesh.

Fungicide efficiency test in laboratory

In the laboratory, the modified methods of Tasiwal et al. (2009) and Suleiman et al. (2009) were used. One week-old *S. rolfsii* cultures were treated by pouring 10 ml of freshly extracted column juice or which had sojourned in a refrigerator for 2 and 15 days at 10°C, a solution of Maneb 80 (100 g in 16 L of water) and melted urea into the cultures. The control plates were not treated. After two days, portions of the cultures measuring 9 mm^2, collected from treated cultures, were transferred with or without sclerotia in four repetitions to sterile Potato Dextrose Agar (PDA) plates. Plates were evaluated one week after the portions had been transferred.

Experiment in pots under shed

Tests were also carried out under natural conditions. The soil used for the trial had been sterilized for 30 min at 80°C. Eight 5-weeks-old tomato plants cv. Tohounvi, grown in individual plastic pots (15 cm × 20 cm) containing sterilized field soil, were inoculated by placing 50 sclerotia from 10 days old cultures between the collar and the root around each plant (Pane et al., 2007). The various phytosanitary treatments were applied seven days after inoculation. Control pots received no treatment. The inoculum was obtained from a *S. rolfsii* strain isolated from the collar of one of tomato plants collected from the field in Ouègbo area (south of Benin Republic). Treatments in pots were similar to those conducted in the field, with the difference that treatment with juice with two applications separated by two weeks and another treatment with a complex of urea and banana column juice (urea was applied one week after banana column juice) were added. Urea was applied in pots with the dosage of 1.5 g per pot. Watering was ensured at the daily rate of 100 ml of water per pot.

Tests in the field

The experiment was carried out in a farmer's field in the forest-savannah transition zone (Ouègbo) in the South of Benin. The area is characterized by a bimodal rainy season with rain from March to July and from September to October with an average precipitation of 1300 to 1800 mm per year and a crop-growing period of 240 to 330 days, a degraded vegetation and sandy soil. It stretches

Table 1. Economic loss calculation methods for control strategies.

States of nature or possible situations	Probability	Alternative action strategies			
		No action (control)	Maneb 80 Action	Urea action	Banana column juice action
No *S. rolfsii* attack	$1-\alpha = 0.5$	R_{01}	R_{m1}	R_{u1}	R_{j1}
S. rolfsii infestation	$\alpha = 0.5$	R_{02}	R_{m2}	R_{u2}	R_{j2}
Expected values		$(1-\alpha)*R_{01}+\alpha*R_{02}$	$(1-\alpha)*R_{m1}+\alpha*R_{m2}$	$(1-\alpha)*R_{u1}+\alpha*R_{u2}$	$(1-\alpha)*R_{j1}+\alpha*R_{j2}$
Economic loss			$[(1-\alpha)*R_{m1}+\alpha*R_{m2}]-[(1\alpha)*R_{01}+\alpha*R_{02}]$	$[(1-\alpha)*R_{u1}+\alpha*R_{u2}]-[(1-\alpha)*R_{01}+\alpha*R_{02}]$	$[(1-\alpha)*R_{j1}+\alpha*R_{j2}]-[(1-\alpha)*R_{01}+\alpha*R_{02}]$

between 06°30'N, latitude north and 06° 33' E, longitude east. A completely randomized block design with five control methods replicated three times was used. The variants sown in plots of 4 ×2.4 m were: (i) non-treated plot, (ii) plot treated with Maneb 80, (iii) plot treated with urea (100 kg/ ha), (iv) plot treated with banana column juice (50 ml/ plant) and (v) plot treated with a complex of urea-banana column juice.

Plots were separated by a trip of non-cultivated land of 1 m wide. The tomato variety was cv. "Tohounvi" obtained from the Vegetable Programme of the National Institute of Agricultural Research of Benin (INRAB). Four-weeks- old tomato plants were transplanted at a spacing of 80 × 60 cm (40,000 plants/ha). Two weeks after transplanting, the different variants were applied. Urea was applied only once at dosage rate of 100 kg/ha. Banana column juice was also applied only once at the rate of 2000 l/ha (50 ml per plant). The chemical fungicide Maneb 80 was applied each week during 8 weeks, with the dosage of 12.5 kg/ha (100 g in 16 L of water). The actual yield was obtained by harvesting and weighted tomato ripe fruits in three square meters along the diagonal of each plot. On the other hand, the potential yield was estimated based on a randomized choice of four vigorous plants per plot.

Assessment of the disease

The number of wilted plants was recorded every two weeks starting from the fungicides application date and up to 75 days. Wilted plants before flowering were marked with a picket. The incidence of the disease was calculated per plot. The efficiency of the fungicides was calculated as the Area Under the Disease Incidence Progress Curve (AUIPC) of six evaluations of the disease; each evaluation was carried out every two weeks. Based on the incidence of the disease and on observation dates, the AUIPC was determined according to the following formula:

$$\mathrm{AUIPC} = \sum_{i=1}^{n} \frac{[(I_i - I_{i-1}) \times (t_i - t_{i-1})]}{2}$$

were I is the mean of incidence at time t_i, t corresponds to days after treatment (application of fungicides); i is the number of evaluations; n=6 is the total number of evaluations (Shaner and Finney, 1977; Jeger and Viljanen-Rollinson, 2001).

Methods of statistical analysis

The Analysis of Variance (ANOVA) was performed using the General Linear Model (GLM) procedure of SAS (SAS Institute Inc., Release 6.12., Cary, NC, USA) on AUIPC and yield data. The Student-Newman-Keuls test was used to compare mean values of AUIPC and yield (prob. = 0.05).

Methods of economic analysis

The economic analysis was based on the estimates of the economic damage on the basis of the incidence of the disease and yield levels on the one hand, and on the estimates of the production costs based on a socioeconomic survey within tomato producers and on the comparison of actual or desired income on the other hand.

The economic analysis considered not only the actual yield but also the potential yield, both having been assessed in the Ouègbo experimental plots, in South of Benin. The potential yield was estimated through a randomized choice of four vigorous plants per plot. Treatments considered for the economic analysis are: (i) no action: untreated plot, (ii) plot treated with Maneb 80, (iii) plot treated with urea, (iv) plot treated with banana column juice.

The efficiency of the method used is demonstrated by the extent to which it reduces yield losses caused by the disease. The efficiency is measured in percentage in relation to each strategy for the control of the disease. It is the ratio of the level of reduced losses to losses due to the infestation.

The yield loss caused by the disease is the difference between the potential yield and the actual yield obtained when no control strategy exists. Loss reduction is the gap between the yield obtained through the planned control and the yield obtained in the absence of any control strategy.

In decision-making with regard to crop protection against diseases and destructive agents, the economic loss appears to be the parameter that is most indicated (Hardeweg, 2001). In the matrix of decision making, envisaged control strategies are regarded as alternative actions. The states of nature are probable ravaging situations due to infestation. In the case of controlling *S. rolfsii,* strategies and states of nature are shown in the decision matrix table of income (Table 1).

In view of the adoption of a new technology, the producer integrates a number of considerations including the risk, the probability α of the disease appearing and causing loss in the area and its variability from one year to another, by taking due account of agro- ecological specificities. The economic analysis focuses on the

Table 2. Comparative effect of tested fungicides on *S. rolfsii* development.

Fungicide	DEAJE	Fungus organ sampled	Fungus development after 7-day incubation	
			Diameter of mycelium (cm)	Number of sclerotia
Banana juice column	0	Mycelium + 6 sclerotia	0 ± 0	0 ± 0
	0	Mycelium only	0 ± 0	0 ± 0
	2	Mycelium + 6 sclerotia	0 ± 0	0 ± 0
	15	Mycelium + 6 sclerotia	0 ± 0	0 ± 0
Maneb 80	0	Mycelium + 6 sclerotia	0 ± 0	0 ± 0
Melted urea	0	Mycelium + 6 sclerotia	0 ± 0	0 ± 0
Control	-	Mycelium + 6 sclerotia	8 ± 0*	123 ± 8.4
Control	-	Mycelium only	8 ± 0	83 ± 2.8

JEAEJ = Days Elapsed After Juice Extraction; * = Maximum diameter of box of knead; **-** = No treatment.

selection of efficient strategies that takes in consideration the risk element in choosing the form of management of the disease (Table 1).

Revenue calculation considers the two situations in presence: No *S. rolfsii* attack and situation of attack. For each situation considered, the revenue coming from each alternative control situation is estimated.

Let us represent Yo, Ym, Yu, Yj and Yi for the potential yield, yields obtained with Maneb 80, urea, banana column juice and with infestation without any intervention (untreated plots) respectively. Cm, Cu, Cj and Co represent the cost of control with Maneb 80, urea, banana column juice and other operating costs (with the exception of specific costs related to the involved control method) respectively. The selling price of the crop upon harvest is represented by p. The net income (R) of each alternative situation in relation to each situation is as follows:

Situation of no *S. rolfsii* attack (Situation 1):

Control: R_{01} = Yo*p - Co
Maneb 80: R_{m1} = Yo*p – Co - Cm
Urea: R_{u1} = Yo*p – Co - Cu
Banana column juice: R_{j1} =Yo*p – Co - Cj

Situation of *S. rolfsii* attack (Situation 2):

Control: R_{02} = Yi*p - Co
Maneb 80: R_{m2} = Ym*p – Co - Cm
Urea: R_{u2}= Yu*p – Co - Cu
Banana column juice: R_{j2} = Yj*p - Co – Cj

The economic losses integrated two types of losses: (1) losses suffered when no action is taken at the time when the disease proves to be raging; (2) losses sustained when an action is taken while the infestation is not obvious on the crop in place. The economic loss is the difference in net revenue between the control strategy envisaged and the "no action" strategy, weighted by the probabilities of infestation and no attack scenarios respectively (Waibel, 1990; Hardeweg, 2001).

RESULTS

Laboratory experiment

Extraction of banana column juice

The comparison of the two techniques for the extraction of the banana column juice shows that with the vegetable mill and according to the degree of maturity of the banana column, 20 to 25 ml of juice were collected by filling with 50 g of banana column. It takes 3 h to obtain 250 ml of juice. On the other hand with the mortar, 500 ml of juice were obtained in one hour with quantity of 2 to 3 kg of rachis.

Fungicide efficiency test

Table 2 shows the comparative effect of banana column juice, Maneb 80 and urea on the development of *S. rolfsii*. In comparison with the control (untreated plates), the three products used had an unfavourable effect on the *S. rolfsii* development. The observation of the cultures seven days after incubation showed no mycelium growth of the treated *S. rolfsii*.

In untreated plates, a development of mycelium growth accompanied with a massive production of sclerotia was observed resulting from the transfer of mycelium with and without sclerotia. Juice extracted between 0.2 and 15 Days Elapsed After Juice Extraction (DEAJE) showed a repressive effect on the development of the fungus.

Field experiment: Application of products

The analysis of the variance on the AUIPC showed a significant difference between treatments (p< 0.0001). The urea – banana column juice complex showed a highly significant AUIPC. Between the banana column juice, urea, Maneb 80 and the control, no significant difference was obtained for the AUIPC. Although differences between the AUIPC of these last treatments are not significant, the lowest area was registered in the treatment with banana column juice while the highest AUIPC was noted for the control (Table 3).

Experiment in pots under shed: Prevalence of the disease in pots

Figure 1 shows the evolution of tomato plant wilt caused

Table 3. Efficiency of fungicides compared to Tohounvi purified local variety.

Fungicide	AUIPC
Banana juice column	264.3 ± 52.1a
Maneb 80	415.7 ± 71.1a
Melted urea	572.3 ± 125a
Control	623.7 ± 33.2a
*Urea – banana column juice complex	5489.0 ± 647b

*= Damaging effect of the urea – banana column juice complex on tomato plants in the field. AUIPC= Area Under the Disease Incidence Progress Curve. Values followed by the same letter are not significantly different on the threshold of 5 %.

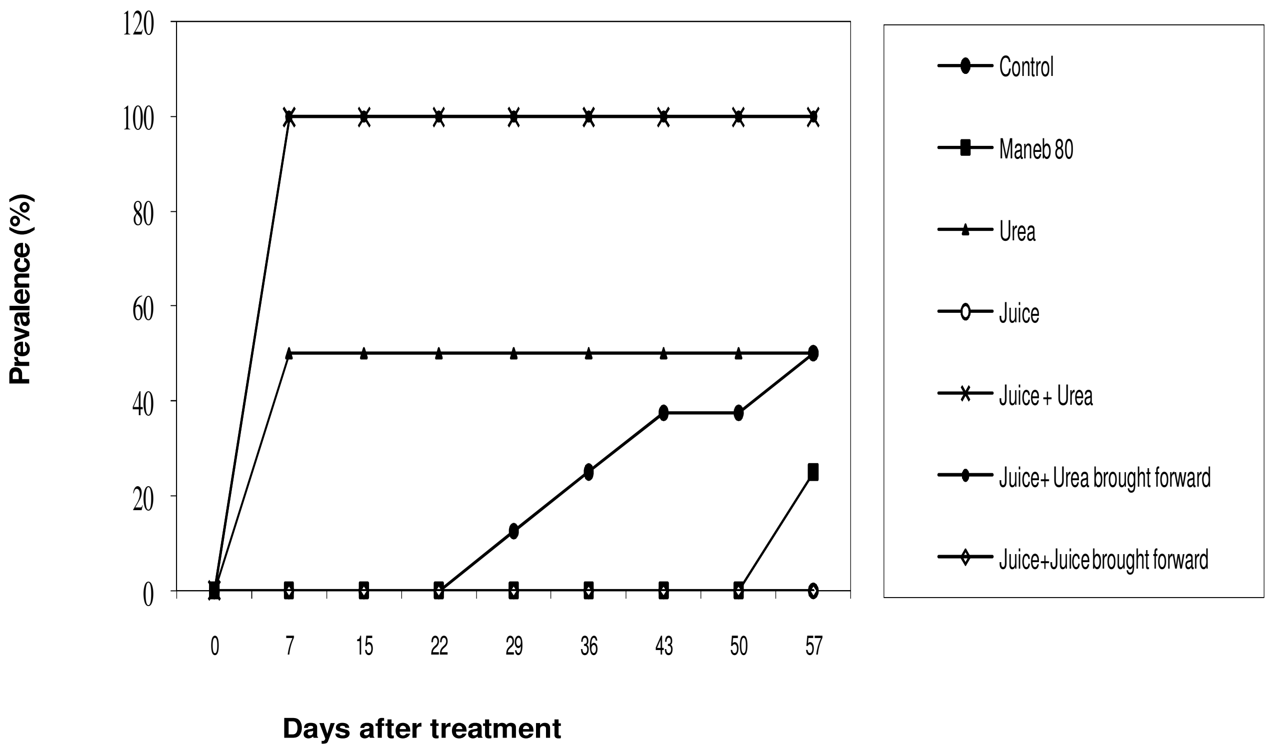

Figure 1. Progress curve of the incidence of tomato wilt disease caused by *S. rolfsii* after the application of different fungicides in pots.

by *S. rolfsii* in the pots. Seven days after the application of urea – banana column juice complex, the proportion of plant wilt was 100%. The same result was obtained when urea only was applied with 50% of wilted plants within seven days after application. Apart from these extreme cases, the trend of the wilt plants in pots was similar to that noted in the field for plots treated with banana column juice only or with Maneb 80. After eight weeks (57 days) following treatment, 50, 25, 0, and 0% of wilted plants were registered respectively for untreated pots, treated with Maneb 80, treated with two applications of simple banana column juice and treated with one application of banana column juice.

Economic evaluation

Tomato yield

In comparison with control (Table 4), gains in yields vary according to the provision of the various fungicides. There are 5.6 t/ha, that is, 27.5% with the provision of banana column juice, 5.1 t/ha, that is, 25.4% with the provision of Maneb 80 and 2.1 t/ha, that is, 10.5% with the provision of urea. In the case of urea – banana column juice complex, a yield loss of about 74% was noted. In relation to the result produced by application of urea – juice complex, the economic analysis focused

Table 4. Tomato yield (t/ha) and yield gains due to the provision of different fungicides.

Treatment	Yield (t/ha)	Yield gain (t/ha)
Banana column juice	25.9 ± 2.1	+5.6 (+27.5 %)
Maneb 80	25.5 ± 5.7	+5.1 (+25.4 %)
Urea	22.4 ± 1.5	+2.1 (+10.5 %)
Urea – banana column juice complex	5.2 ± 2.1	-15.0 (-74.0 %)
Control	20.3 ± 0.4	

Table 5. Efficiency of control strategies.

Control strategies	Loss reduction (t/ha)	Efficiency of control strategy (%)
Maneb 80	25.5 - 20.3 = 5.2	(5.2 / 11.9)*100 = 44
Urea	22.5 - 20.3 = 2.2	(2.2 / 11.9)*100 = 19
Banana column juice	25.9 - 20.3 = 5.6	(5.6 / 11.9)*100 = 48

mainly on the other control methods: untreated, urea, Maneb 80 and banana column juice.

Losses due to infestation and efficiency of control strategies undertaken

The average potential yield evaluated in plots is Yo = 32.2 t/ha (±3.0). By considering the yield obtained in the absence of any intervention on the disease which is Yi = 20.3 t/ha, the loss attributable to the attack in the study environment is 11.9 t/ha. Control strategies under evaluation turn towards reduced yield losses. The efficiency measure gives results in the Table 5. It follows from the results that banana column juice technically appears more efficient followed by Maneb 80 in the reduction of yield losses due to *S. rolfsii* infestation caused to tomato.

Control strategies' costs and net revenue

1. Period of abundance: The average selling price in the period of abundance in the south of Benin was 40 fcfa/kg at the time of the experiment. The calculation of production costs integrates specific charges of each protection measure and other operating costs (Table 6). Results show that specific charges with Maneb 80 and banana column juice are high and have an adverse impact on net revenue. The income appears to be greater with the use of urea as a control method.
2. Matrix of control strategy decisions envisaged in the period of abundance of tomato: Specific analyses in a controlled environment show that *S. rolfsii* is responsible for at least 50% of the damage caused in the survey area. This percentage constituted the incidence of the disease in the area and points out the risk of damage caused by the fungus (α=0.5). Table 7 shows the results of these strategies. In the view of the extent of the damage which is mainly due to *S. rolfsii* and to the cost of treatment applied to each envisaged control strategy, it follows that only the "urea action" is economically profitable while none of the two other strategies is economically efficient when they are compared with the "no action" strategy.
3. Off-season period: In the off-season period, the average selling price of tomato is 300 fcfa/kg. Results in Table 6 show that in this case, despite the high level of specific charges of the treatment with Maneb 80 and banana column juice, the charges have no negative impact on the net revenue. It appears better with the use of banana column juice as a control method.
4. Matrix of control strategy decisions envisaged in the off-season: It follows from the analysis of Table 7 that only the "urea action" strategy is economically profitable while none of the other two strategies is economically efficient when compared to the "no action" strategy. However, when the economic profitability of the "urea action" is compared in terms of period of production, it results that this strategy is more profitable in the off-season period than in the period of abundance.

DISCUSSION

The extraction of the banana column juice by pounding is a technique whereby much juice is obtained in record time. It is more practical and available for farmers since electricity is not everywhere, mainly in rural areas where mills were used.

The banana column juice, the melted urea and Maneb 80 (100 g in 16 L of water) were efficient against *S. rolfsii*

Table 6. Costs and net revenue of control strategies.

	Control strategies	Yield obtained (t/ha)	Receipts (fcfa/ha)	Control strategy specific costs (fcfa/ha)	Other costs	Total costs	Net revenue (fcfa/ha)
Period of abundance	Maneb 80	25.5	1020000	1578125	250000	1828125	-808125
	Urea	22.5	900000	25000	250000	275000	625000
	Banana column juice	25.9	1036000	1003125	250000	1253125	-217125
	No action	20.3	812000	0	250000	250000	562000
Period of scarcity	Maneb 80	25.5	7650000	1578125	250000	1828125	5821875
	Urea	22.5	6750000	25000	250000	275000	6475000
	Banana column juice	25.9	7770000	1003125	250000	1253125	6516875
	No action	20.3	6090000	0	250000	250000	5840000

Table 7. Decision matrix.

	States of nature or possible situations	Likelihood of disease to break out	Alternative action strategies			
			No action (fcfa/ha)	Maneb 80 action (fcfa/ha)	Urea action (fcfa/ha)	Banana column juice action (fcfa/ha)
Period of abundance	No *S. rolfsii* attack	$1-\alpha = 0.5$	1038000	-540125	1013000	34875
	Infestation by *S. rolfsii*	$\alpha = 0.5$	562000	-1016125	537000	-441125
	Expected values		800000	-674125	819000	-91125
	Economic loss			-1474125	19000	-891125
Period of scarcity	No *S. rolfsii* attack	$1-\alpha = 0.5$	9410000	7831875	9385000	8406875
	Infestation by *S. rolfsii*	$\alpha = 0.5$	5840000	5821875	6475000	6516875
	Expected values		7625000	6826875	7930000	7461875
	Economic loss			-798125	305000	-163125

according to laboratory tests. Banana column juice freshly extracted or extracted two or fifteen days prior to application, melted urea and Maneb 80 (100 g in 16 L ofwater) inhibits not only the growth of the mycelium but also the germination of the sclerotia. This result explains that all these tested products contain a substance which inhibits the germination of *S. rolfsii.* The inhibition would probably be due to the presence of antifungal compounds in banana column juice, melted urea and Maneb which altered the mode of action of the fungus. Our result corroborates with those achieved by Toribio (1989) cited by Messiaen et al. (1991) according to which the germination of sclerotia and the growth of the mycelium of *S. rolfsii* are inhibited by soluble nitrogenous compounds, in the form of urea in particular. This result shows also that banana column juice maintains its efficiency till 15 days after harvest. As for the banana column juice, it was efficient not only in the laboratory, but also under shed and in the field. These results confirm Toribio (1989) cited by Messiaen et al. (1991) which mentioned that the chopped pseudo-trunks (tree) of banana have an unfavourable effect on *S. rolfsii*. According to the same author, the most remarkable action is that of the banana column juice, efficient in watering not only in concentrated form but also when diluted up to the tenth. Banana and its pseudo stem contain pathogenesis proteins possessing antimicrobial properties (Barre et al., 2000). As revealed on unripe plantain banana pulp (*Musa sapientum* L. var. *parasidiaca*), the extracted leucocyanidin and a purified synthetic leucocyanidin had similar protective effect against aspirin-induced erosions (Lewis et al., 1999). Through the results of Barre et al. (2000) and that of Lewis et al. (1999), the antifungal compounds of banana plant may be a pathogenesis protein or a leucocyanidin.

Besides banana column juice, the efficiency of other botanical extracts has been revealed on *S. rolfsii*. The aqueous extract of *Moringa oleifera* inhibits the development of *S. rolfsii* a causative agent of damping off and stem rot of cowpea (Adandonon, 2004). On southern blight caused by *S. rolfsii* on cowpea, Ahohuendo et al. (2005) reported that *Cymbopogon citratus* at the concentration of 5% and *Hyptis suaveolens*, *Carica papaya* and *Azadirachta indica* at the concentration of 15% prevent the growth of the fungus. Khanzada et al. (2006) revealed that, *in vitro*, the efficacy of leaf extract of *Datura alba, Calotropis procera*, and *Cannabis sativus* was at 1.5, 2 and 2% respectively. Jalal and Ghaffar (1992) studied antifungal characteristics of *Ocimum sanctum* and found that its leaf extract completely inhibited the growth of *S. rolfsii* and other fungi.

Inhibitory effects of plant leaf extracts have also been observed on viruses and other soil fungi (Baker, 1981; Kuc and Shain, 1977). To control major plant diseases, the use of barks and corks of commonly grown trees and shrubs is also a feasible way. Leaf decoction of *Acacia nilotica*, *Calotropis procera*, *Datura stramonium*, *Dodonea vicosa* and *Rhazya stricta* were found to be effective in processing urediospore germination on detached leaves of wheat (Rahber-Bhatti, 1988).

Volatile fraction of two medicinal plants, *Azadirachta indica* and *Eucalyptus globules* were more effective in suppressing the sclerotial germination of *Macrophomina phaseolina* than non-volatile fractions (Dubey and Kishore, 1990). Leaf extract of *Datura stramonium* reduced the development of rust pustules on the leaves of wheat (Hussain et al., 1992). Herbaceous plants have been widely used in various ways against the fungal diseases. Aqueous leaf extract of *Allium sativum*, *Datura alba* and *Withana somnifera* inhibited the growth of *Alternaria alternata* and *Myrothecium roridum* (Mughal et al., 1998).

In pots and in the field, all urea – based treatments were more destructive than curative. This would be linked to the fact that urea as solution, in contact with the roots of plants would have an herbicidal effect. The most regrettable result is that obtained from the treatments urea - banana column juice complex applied in the same day or brought forward. It is important to note the damaging effect that this complex has had on tomato plants both in pots and in the field. The isolations from collars and roots of some withered plants after the application of urea - banana column juice complex revealed no attack of *S. rolfsii* or other pathogens causing tomato wilt. The 96 to 100% of incidence of less than one week noted in pots and in the field in plots having received a complex of urea and column juice treatments explain the herbicidal effect that the association of urea – banana column juice has induced on tomato plants. Other explanation to this result is that the urea in contact with the root may induce the osmosis system by which the sap of tomato plant has been drained toward the urea and consequently caused the wilt of the plants.

The high yield obtained in plots treated only with banana column juice explains the efficiency of the treatment. On the other hand, the incidence of 0% obtained in pots confirms this result.

In the context of this work, the incidence of wilted tomato plant due to *S. rolfsii* is 50% while the diagnostic study of tomato diseases carried out in the South of Benin by Sikirou et al. (2001) revealed a wilt incidence of 35 to 90% in the Commune of Toffo which depends on the area of Ouègbo (the experimental site). Their result would perhaps be linked to the effect of a complex of pathogens on tomato.

From an economic profitability point of view, it is not only the urea action control strategy which has been profitable in the period of tomato scarcity or abundance. The absence of a market where banana column juice is sold has enormously increased the production costs of banana column juice. As a matter of fact, it is the purchasing cost of the whole banana bunch that has been considered in the analysis while the juice is only a by-product of the bunch.

Considering that banana tree is full of sap comparatively to banana column may lead to experimentation of testing the efficiency of banana tree sap on *S. rolfsii*. The efficiency of the banana tree sap on *S. rolfsii* would enormously reduce the cost related to the application of banana by-products as control means.

Conclusion

Banana column juice, Maneb 80 and melted urea have an inhibiting effect on *S. rolfsii*. However, banana column juice is technically more efficient than Maneb 80 and urea. In the field, banana column juice and Maneb 80 were technically and economically profitable only in off-season period (period of tomato scarcity). Urea was not only technically efficient but also economically profitable irrespective of the production period. The mixture of banana column juice and urea is an amendment harmful to tomato growing.

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