Protocol to evaluate phyto-pharmaceutics products (PPP) deposition on banana crop from different types of ground based sprayers

Eric Cotteux, Bernard Bonicelli, Jean Paul Douzals

International Conference of Agricultural Engineering
AgEng 2014 Zurich 6–10 July

Ref: C0501

Protocol to evaluate phyto-pharmaceutics products (PPP) deposition on banana crop from different types of ground based sprayers

Eric Cotteux and Bernard Bonicelli and Jean-Paul Douzals, IRSTEA 361 rue Jean François Breton, BP5096 34196 Montpellier cedex 05 France

Abstract : Banana crop is dramatically exposed to Sigatoga disease. Until now, the control was operated thru aerial application but national and European legislations banned aerial spraying on crops (Directive 2009/128/CE), arguing of human health and environment safety (PAN, 2004). The Optiban project was launched in 2008 to meet the requirement of the Food and Agriculture Ministry and the Groups of banana growers of Guadeloupe and Martinique (UGPBAN). It aims at improving a ground based system to replace aerial application (Rombaut, 2011) ; agronomic goal is to treat principally the upper leaves. For this purpose an original mistblower named Optiban was specifically designed. In parallel, other systems have been developed or adapted to spray from under the canopy (Knapsack sprayer mounted on ATV, low volume pneumatic sprayer). Up to now, there is no experience about the efficacy of these different systems for banana crop and a fast method to evaluate distribution of the product in the canopy appears to be an imperative requirement. This paper introduces protocols specifically designed for the evaluation of deposition on banana as well as results for different types of sprayers.

Keywords: Spray Deposit protocol, banana protection, Black Sigatoka,

1 Introduction

Evaluation of the deposition of phyto-pharmaceutic products (PPP) in the different environmental compartments which constitute crop, air and ground is definitely a main issue for agronomists. From recent years, a new paradigm arose concerning PPP dispersion and this new paradigm can be illustrated by "the right dose in the right place". Two complementary research axes have so to be investigated. First one concerns the determination of the minimum and sufficient quantity of product which should be applied to protect the crops from different diseases. This point won't be discussed in this paper. The second one consists in applying this minimum dosage. From now on, most of sprayers haven't been initially designed with those integrated constraints. To compensate this, most of manufacturers tend to improve their sprayers with more or less success. In some cases, sprayers are even banned from the crop and are replaced by fixed spraying systems (Landers & Agnello, 2013). Many research teams developed different kind of patternators to characterize distribution of the spray mix in canopy (Gil, Landers, Gallart, & Llorens, 2013) or used modelling to evaluate dispersion in the canopy. Although those approaches are useful and provide many interesting data, the problem remains complex as canopy is rarely homogeneous. In the case of banana crop, leaves interfere one with the others limiting the spray penetration whatever is the sprayer type. Thus information about the distribution of product on a vertical or horizontal patternator gives only a theoretical deposition on targets. The most precise way to quantify the product distribution in the canopy is to sample directly in the canopy area. In several works deposition on canopy has been investigated using artificial collector or by sampling part of the vegetation (Hoffmann et al., 2009) (Sasaki, Teixeira, Fernandes, Monteiro, &

Rodrigues, 2013). This approach is realistic when vegetation is quite homogeneous and when it is possible to get a good sampling with reasonable quantity of material. Another point is to make the assumption that deposition on one leaf is representative of a specific point in the canopy. For banana crop, the deposition on vegetation is not homogeneous because of leaves overlapping. Moreover leaves dimensions are quite impressive (2 m to 2.5m length and 1 to 1.5 m large) and so each leaf collects product at several heights. For those different reasons, it has been decided to elaborate a specific protocol. The general idea is to sample the total volume of canopy at different heights and different geographical positions. This paper presents results of the specific protocol developed for this purpose.

2 Evaluation of different type of sprayers

The main disease for long in banan crop has been Yellow Sigatoka induced by *Mycosphaerella musicola* and more recently with Black Sigatoka induced by *Mycosphaerella fijensis* which tends to compete with *M*. *musicola*. Black Sigatoka is the worst in terms of production losses and requires an increased number of fungicide applications. As 12 treatments a year are generally sufficient to control Yellow Sigatoka but more than 40 are necessary to control Black Sigatoka in most infested areas (South America – Africa). Aerial applications used to be the main way to treat diseases of banana crop. Because aerial treatments have been banned in EU countries for several reasons related to E.U. regulation and by lobbying of environmental associations, new kinds of sprayers have been designed to replace fixed wing or helicopters. Some terrestrial solutions such as mist blowers already exist and are used in different parts of the World but appear to be unadapted to specific constraints of ground terrain in French West Indies. To face this critical issue, banana producers contributed in developing specific system such as Optiban sprayer and tested some other commercial products such as ATV based mist blowers or other ground based spraying systems such as airblast or pneumatic sprayers. Two main categories can be defined depending on the location of the spray emission i) over the top of the vegetation or ii) underneath the vegetation. Because none of those equipments have been tested before, it was first necessary to evaluate the way those systems will apply the product on the vegetation and especially the location of spray deposits. Because the fungi will first colonize the newer leaf at the top of the plant, the fungicide should preferably be sprayed at first sight on this site (over the canopy). Meanwhile a second step of fungi development will take place at the lower side of the leaf. In this case spraying underneath the vegetation could provide advantages. Hence it appears necessary to evaluate the deposition efficiency whatever the orientation of the spray.

3 Materials and methods

3.1 Collectors

The collectors are constituted of black PVC roll-on of 13 cm diameter originally used as soft irrigation pipes. A piece of 5 m long is slipped on a pole. Each pole is itself shoved on a stick thrust in the ground at specific positions. A grid of several collectors specifically designed for this study is installed in the crop to form the measurement device. The sprayer applies the mixture at the proper dosage (under controlled speed and flow rate). After spraying, the collectors are retrieved and the quantity of product is measured through spectrophotometry technic. PVC bands are cut in 10 slices of 50 cm long starting from the bottom of the pole. When a slice is collected, extraction of tracer is directly made by washing the pieces in a specifically designed extraction tube filled with 80 ml of desaromatized oil solvent. (European reference EC 918-481-9). The extraction volume is stored at room temperature for a maximum of 4 hours and a fraction is collected to be analyzed at laboratory with a spectrofluorimeter Jenway 6100 (excitation 450 nm ; emission 500 nm).

3.2 Mixture and tracer

For Optiban 3.1 and Baneole 420 the mixture sprayed is mineral oil Banole® (TOTAL FLUIDES,24, cours Michelet, 92800 PUTEAUX) where a tracer Radglo CFS 006 ® (Radiant Color Europarklaan 1046, 3530, Belgium) is dissolved at the concentration of 1 g/L. For the Cima the mixture is an emulsion made with 7 liters of Banole® and 23 liters of water added with 0.7 liter of Heliosol® as emulsifier. The last emulsion contains 1 g/L CF S 006.

3.3 Ground based sprayers evaluated

Three types of sprayers have been tested. First, Optiban 3.1 sprays over the canopy and the two others named Baneole 420 RPM and CIMA spray underneath the canopy. *Table **1*** describes sprayers technical parameters and Table 2 spraying parameters

		
Name : Optiban 3.1 Engine power : 87 CV Wind flow rate : 5600 m^3/h Diffusers : 2 outlets with 1 nozzle EXA white and 1 mirror yellow Flow rate : 1.2 L/min Pressure : 3 bars	Name : ATV Banéole 420 rpm Engine power : 6.5 CV Wind flow rate : 4100 m^3/h Diffusers : 2 outlets with1 nozzle ATR each Flow rate : 0.6 L/min Pressure : 3 bars	Name : CIMA Engine power : 65 CV Wind flow rate : 7750 m^3/h – 175 m/s Diffuser : 2 X 4 pneumatic outlets Pump Flow rate : 140 L/min Pressure : 3 bars

Table 1 : above and below canopy sprayers

Table 2: Spraying parameters

Parameter	Optiban 3.1	Baneole 420	CIMA
Forward Speed (km/h)	4.5	9.0	4.5
Spray Swath (m)	20	10	10
Flow rate (L/min)	2.4	1.2	5
Application volume (l/ha)	15	15	70

3.4 Measurement devices

Two different measurement devices are settled in regards to the crop configuration or measurement objectives. First device presented in figures 1, 2 and 3 is dedicated to the comparison of the mixture collection on the pole and on leaves. This comparison was made for Optiban 3.1 and the ATV Baneole. The second protocol presented in figures 4,-5 and 6 is dedicated to the evaluation of vertical and longitudinal spray distribution for Optiban 3.1 and CIMA.

Figure 1 : collection device around one banana plant

Figure 2 : leaf collect

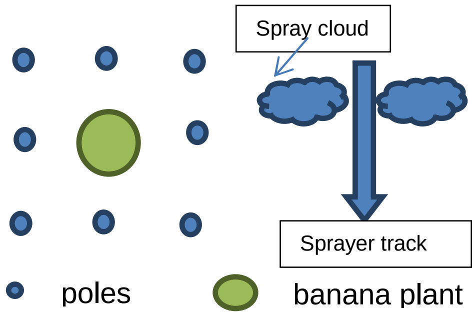


Figure 3 : Top-view of deposition measurement device between poles an leaves

Figure 4 : vertical and longitudinal deposition measurement device

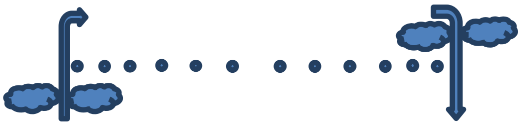


Figure 5 : collectors location for Optiban 3.1. Spray range is 10 m each side

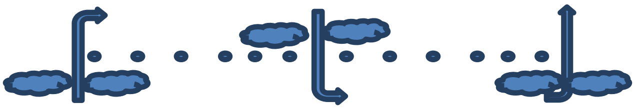


Figure 6 : collectors location for CIMA sprayer. Spray range is 5 m

3.5 Comparison of deposition on leaves and collectors

An issue of this protocol was to validate the response of the collectors in regards to the deposition on banana leaves. For this purpose a specific device has been designed shown in figures 1-2-3. Recovery efficacy of the product on leaves has been checked. A known quantity of tracer diluted in Banole® is manually distributed on a leaf and then recovered after different laps of time by washing the leaf with a known volume of solvent. Different volumes of solvent have been tested so as to determine the optimum volume to retrieve the maximum of product. A volume of 1 liter per leave of about 2 m² and a time of extraction of 45 minutes were necessary to recover more than 90% of the product. The shorter is the time of extraction after spraying, the better is the washing efficacy. Meanwhile washing within 1 hour is acceptable if the extraction time is at least of 45'. The recovery of mixture on PVC collectors was also measured and recovery was 100% in this case.

3.5.1 Selection of the banana plants

All measurements were made in a two-year old plantation. A consequence is that at each original place, at least three banana plants are growing from the same stock. Each plant is at a vegetation stage of about three months earlier from the older. Only adult banana plants freshly harvested were identified for the measurement. Due to the plantation scheme in twin rows, the banana plants are positioned at different distances from the sprayer. Thus different banana plants located at different distance from the diffuser have been chosen. After the spray application, each leaf is cut starting by the oldest one (lowest one), measured in dimensions and immediately washed with 1 liter of solvent in a large tray. A pool of 2 or 3 leaves is made so as to get at last 2 or 3 samples. The leaves are stirred and the tray is vigorously shaken. The pseudo-trunk is not washed.

3.5.2 Expression of the results

As collectors are supposed to sample the vegetation plane, it is assumed that the collectors intercept the same quantity of mixture as by a leaf if this one were at the same location. The quantity of mixture is expressed in µL. The surface of interception considered at each position is the whole surface of the slice i.e. 0.13 X 0.5 = 0.065 m². The surface of each leaf (Ls) is calculated according to the expression: Ls= 0.6 X L x l where 'L' is the Length of the leaf and 'l' is the larger width dimension. This formula has been determined after precise measurement of leaf area with image analysis. The spray deposition on leaves or on the collector is expressed in µL/m².

4 Results and Discussions

4.1.1 Comparison of deposition on leaves vs poles for sprayer Optiban 3.1

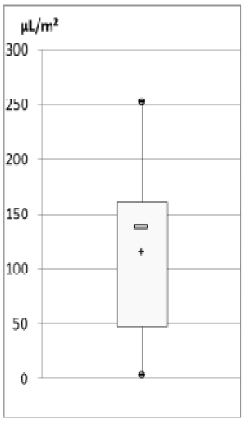
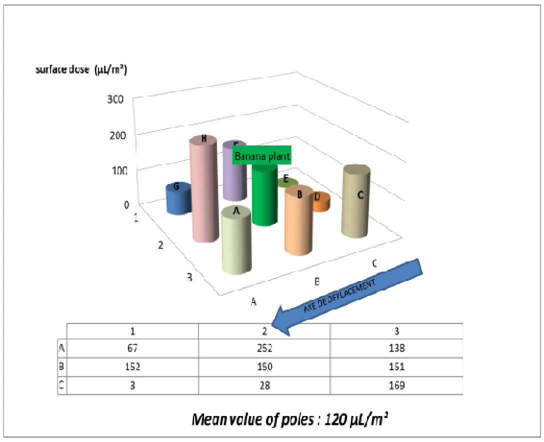


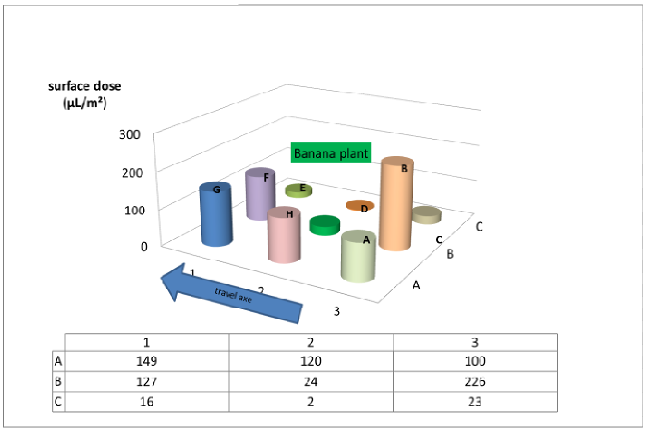
Figure 7 : box plot for poles results



	1	2	3
A	67	252	138
B	152	150	151
C	3	28	169

Figure 8 : comparison n°1 of deposition on pole vs deposition on leaves

Because the leaves are located between 2.5 and 5.0 m height, we compare the results obtained on the leaves to the results obtained on the 5 upper slices of 8 poles located around the banana plant. Figure 7 shows that the results are quite scattered but the median value matches with the mean value of the leaves result. Figure 8 shows the spatial distribution of results.



	1	2	3
A	149	120	100
B	127	24	226
C	16	2	23

Figure 7 : comparison n°2 of deposition on pole vs deposition on leaves

A second experiment shows different results. In this case the quantity of mixture measured on the leaves is quite smaller than on the poles. From those two results it is difficult to assume that the pole describe precisely the quantity of mixture which really is intercepted by the leaves.

4.1.2 Comparison of deposition values on leaves vs. poles for sprayer Baneole 420

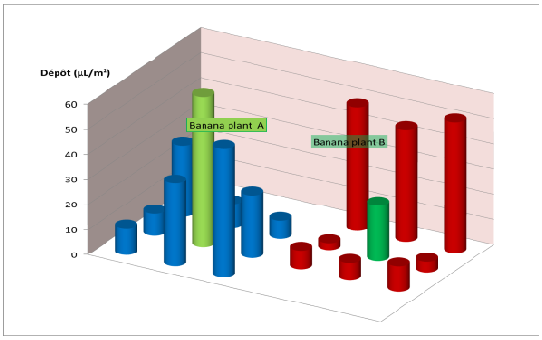


Figure 9 : comparison n° 3 of deposition on poles vs. on leaves

For this test, two banana plants were chosen from each side of a twin row. The sprayer treats one row during the forward travel and the second row during the return travel. The results show that the mean value for pole of both banana plants are very close 21.7 and 22.1 µL/m² respectively for A and B plant but are still very variable. The mean value for leaves deposition of A and B is respectively 59.6 and 22 µL/m².

4.1.3 Results for vertical deposition for both sprayers

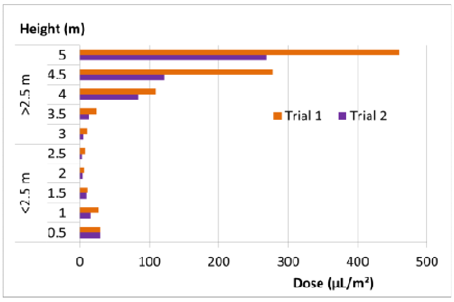


Figure 11: vertical repartition for optiban 3.1

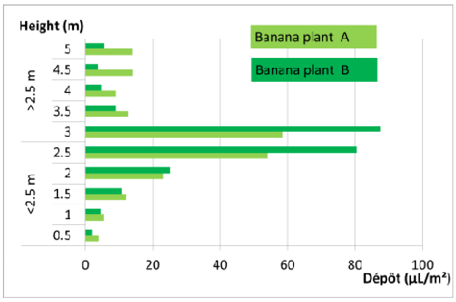


Figure 11 : vertical repartition for Baneole

Another way to analyze the results is presented here after in Fig. 11 and Fig. 12. We can clearly differentiate the two profiles of the different sprayers. Deposition from Optiban 3.1 reaches the target of upper leaves as for underneath canopy sprayer (fig 12), the deposition is concentrated around 3 meters height. It is important to notice that the global quantity of mixture deposition is much higher for Optiban 3.1 than for Baneole (Fig 13).

4.1.4 Results for longitudinal distribution

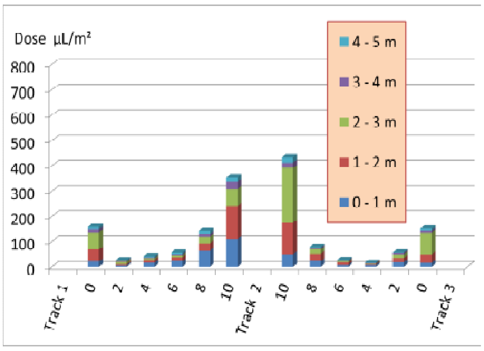


Figure 13 : Longitudinal repartition for CIMA

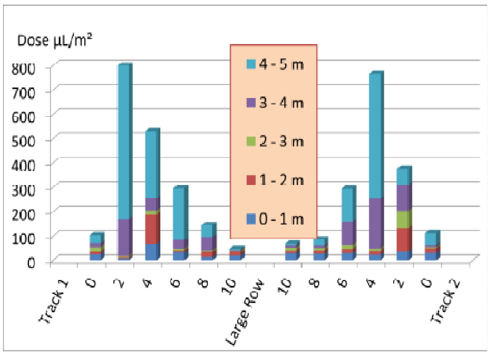


Figure 13 : Longitudinal repartition for Optiban 3.1

Optiban 3.1 and Cima were spraying on the same field. The collection device for both apparatus is the same. Figure 13 and Figure 14 show the global deposition on the poles from 0 (ground) until 5 meters. Each color represents a height of 1m on the collecting device. The results clearly show that few of the mixture reach the upper leaves for CIMA sprayer in contrary to Optiban 3.1 sprayer.

5 Discussions

The quantitative evaluation of the spray deposition on a tree-size crop is a critical issue. The vegetation geometry and density are important parameters which influence the deposition (Stover, 2002). Several authors developed systems to measure deposition on leaves for several crop (Furness & Thompson, 2006) or specifically in banana (Washington, Cruz, & Fajardo, 1998). We were inspired by this last work to define our own protocol but we took the option to promote continuous collectors contrarily to spot collectors. Another bias consisted in sampling in the leaves environment instead of onto the leaf itself. Those two options were chosen so as to limit the deposition variability; very often observed during latest measurements we made. The results show that for both types of sprayers, 8 poles surrounding a banana plant is adequate to evaluate mixture deposition variability. The results could have been more accurate by analyzing leaf deposit considering height compartments. This has not been done because of limited time and would probably impact the mixture extraction. However the order of magnitude of the result is quite consistent for pole- and leaf- deposition although it appears to be twice for one experiment. Concerning the use of vertical profiles, this protocol clearly exhibits the performances of the different types of sprayers and could be useful also to setup the sprayer diffusers orientation so as to reach the target properly.

6 Conclusion

The protocol developed in this study generated a 3D map of mixture deposition for different types of sprayers in banana crop and allowed the comparison of beneath vs. underneath canopy spraying. This protocol could also be useful to optimize the orientation of diffusers or to test new diffusers. Unless it could not precisely give the quantity of product which could be intercepted by the leaves, the order of magnitude of recovery is consistent with the measurements on the leaves. This protocol offers the possibility to get quantitative information for mixture distribution in the crop and could be enhanced with spray quality information from sensitive papers. The pole appears to be good device to measure mixture distribution inside the vegetation. Meanwhile a solution for pole conception must be found in order to reduce the duration of experiments.

7 Acknowledgements

This work has been funded by EU-FEADER, UGPBAN and French Minister of Agriculture.

8 References

Directive 2009/128/CE. Directive for sustainable use of pesticides. *JOCE.L309*, 71-86.

Furness, G. O., & Thompson, A. J. M., D. W. L. (2006). A visual droplet number rating chart and fluorescent pigment sprays to estimate chemical deposition and spray coverage on plant foliage. *ASPECTS OF APPLIED BIOLOGY, 77*, 171-178.

Gil, E., Landers, A., Gallart, M., & Llorens, J. (2013). Development of two portable patternators to improve drift control and operator training in the operation of vineyard sprayers. *Spanish Journal of Agricultural Research, 11*(3), 615-625.

Hoffmann, W. C., Farooq, M., Walker, T. W., Fritz, B., Szumlas, D., Quinn, B., . . . Robinson, C. A. (2009). Canopy penetration and deposition of barrier sprays from electrostatic and conventional sprayers *Journal of the American Mosquito Control Association,, 25*(3), 323-331.

Landers, A., & Agnello, A. (2013). *Further developments of a fixed spraying system for high density fruit trees.* Paper presented at the Suprofruit 2013, Valencia Spain.

PAN. (2004). Pesticide Action NetworkEurope position on aerial spraying. 2.

Rombaut, M. Cotteux, E. ; Carre, M. ; Didelot, D. (2011). Fighting Banana Sigatoka diseases in the French West Indies Eco-conception of an innovative ground solution *Sciences Eaux et Territoires, n° Spécial. Optiban, des solutions innovantes pour le traitement des bananiers*, 10-16.

Sasaki, R. S., Teixeira, M. M., Fernandes, H. C., Monteiro, P. M. D., & Rodrigues, D. E. (2013). Deposition and distribution uniformity of spray in coffee plants using electrostatic spraying. *Ciencia Rural, 43*(9), 1605-1609.

Stover, E., Scotto D., Wilson C., Salyani M. (2002). Spray applications to citrus: overview of factors influencing spraying efficiency and off target deposition. *University of Florida Integrated Database,*, 1-11.

Washington, J. R., Cruz, J., & Fajardo, M. (1998). Detection of chlorothalonil in dew water following aerial spray application and its role in the control of black Sigatoka in banana. *Plant Disease, 82*(11), 1191-1198. doi: Doi 10.1094/Pdis.1998.82.11.1191