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Effectiveness of prophylactic methods in fruit fly management in northern Côte d'ivoire

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Abstract
The third most important fruit exported from Côte d'Ivoire after pineapple and banana, the quantities of mangoes exported over the last five years have increased from 10,179 tonnes in 2011 to more than 33,100 tonnes in 2017. Despite its economic importance, a large part of the production does not reach the market due to pressure from flies of the Tephritidae family. In order to reduce this pressure in three northern localities (Korhogo, Sinématiali and Ferkessédougou), a new fly management approach has been initiated. The objective of this study is to evaluate the effectiveness of two prophylactic control methods, namely ploughing plus destruction and collecting plus augmentorium compared to a control (village practices). This work was carried out in the orchards of 9 producers divided into 3 groups, including one group per locality. Method one (1) consisted of collecting the fallen fruit from the ground and placing it in an augmentorium. The second was to plough the soil in order to destroy the pupae buried in the soil. Analyses have shown that both prophylactic methods significantly reduce fly attack rates on mangoes. These methods reduce fly attacks by 7 to 10% from one year to the next and by 50 to 55% compared to control plots. They are also easy to install and less expensive.
However, no significant difference could be established between the two prophylactic methods at P=0.685>0. This new control method is to be used to reduce the use of chemicals in orchards.

Keywords: fly, prophylactic control, tephritidae, mango

1. Introduction
At the forefront of fruit diversification in Côte d'Ivoire, mango now plays an important role in the economic development of the country's northern region, which until now has focused mainly on cotton cultivation. Mango is the third fruit exported from Côte d'Ivoire after pineapple and banana. In international markets, Côte d'Ivoire is the second largest supplier of mango after Brazil. More than 95% of the exported volumes are destined for the European market. The quantities exported over the last five years have increased from 10,179 tonnes in 2011 to more than 33,100 tonnes in 2017 [1]. These performances have been obtained following quality training and the widespread use of approved packaging centres for mango processing. The development of the sector helps to slow the rural exodus and contributes to the poverty reduction strategy because it generates income for the various actors involved: from producers to exporters, including packers, harvest technicians, processors and permanent or seasonal transporters [2]. Despite this economic importance, mango production in Côte d'Ivoire is limited by fruit fly damage. This damage constitutes a major obstacle for exports due to the devaluation of the goods and the Maximum Residue Limit (MRL) measures imposed by European countries [3]. The Ivorian Government has been informed of the high number of interceptions of mangoes contaminated with harmful organisms in recent years. These interceptions, which are mainly due to the presence of fruit fly larvae of the Tephritidae family, reached a high level during the 2014 season (62 containers seized in 2014 compared to 10 seized in 2016 and 32 in 2017). The damage caused by these quarantine insects is bites made by fly females to lay their eggs inside the fruit. At hatching, the larvae dig galleries in the fruit, thus depreciating their commercial value.
In addition, these galleries and bites are a route for the penetration of fungi and bacteria that are responsible for rot and premature fruit drop. Pupaison occurs in the soil and flies emerge a few days later. Chemical control having shown its limits, the search for an alternative method constitutes a challenge for a sustainable and efficient production of mango. The objective of this study is to evaluate the effectiveness of two prophylactic control methods (ploughing + destruction and collecting + augmentorium) compared to a control (village practices).

2. Material and Methods
2.1 Study Area
This study was carried out in three cities in northern Côte d'Ivoire. Tests were carried out in orchards in the Korhogo areas (between latitudes 09°30. 508' N and 09°35.265' N and between longitudes (005° 42.996' W and 005°13.182' W); Sinématiali (between latitudes 08°50.394' N and 09°07.214' N and between longitudes (005°10.988' W and 005°13.421 W) and Ferkessédougou (between latitudes 09°39.932' N and 09°31.953' N and between longitudes (006°29.327' W and 006°29.875 W). the area of each orchard is about 4 hectares.

2.2 Biological Materials
The organic materials consist of mango Kent variety fruit (*Mangifera indica*) and fruit fly (Diptera: Tephritidae) from harvested fruits.

2.3 Technical equipment
2.3.1 Insecticides
DDVP or dichlorvos (2-dichloro, 2-vinyl and dimethyl

phosphate) was the only insecticide used to kill flies in orchards.

2.3.2 Attractive
Three sexual attractants (Methyl Eugenol, Terpinyl acetate and Torula) and insecticides were deposited in Tephri Trap traps placed 2-4 m above the ground in the shaded canopy to prevent them from being damaged in the presence of the sun. Attractions were renewed in each orchard once a month and insecticides every two months.

2.4 Methods
2.4.1 Data collection
The villages and producers were chosen according to the following criteria:
- Easy access to the orchard,
- The area of the orchard (at least 4ha),
- The Presence of varieties of commercial interest, particularly Kent
- The availability of fruits throughout the experiment.

Prophylactic control trials have been set up in close collaboration with producers. Nine (9) producers in groups of three in each community were selected. Two prophylactic control trials were implemented in addition to the control.
E1 = Test 1 = Non-destruction collection + augmentorium,
E2 = Test 2 = labour + destruction of pupae
E0 = Control test = village practice

Each test, repeated 3 times, was applied in each locality. Data collection in the different localities was carried out on a weekly basis.
For Test 1, fruit that fell to the ground was collected weekly. Collection began during the orchard harvest period, i.e. in April, May, June and July, for the two sampling years (2016 and 2017). They were collected with the help of baskets and put in augmentoria whose principle was to prevent the flies from flying but to allow the natural enemies of the flies to multiply. An augmentorium was used per orchard and per locality.
For test 2, black plastics were used to destroy the fallen fruit. A plough attached to two oxen was used for ploughing orchards to destroy the pupae buried in the ground.
For each sampling, five (5) fruits per tree were collected from twenty (20) trees per orchard randomly selected from each orchard per locality, for a total of 100 fruits per locality. Sampling was done both in treated and control orchards.
The zero state of the orchards was assessed by sampling prior to the application of the different control methods in all orchards in the trials.

2.4.2 Evaluation of prophylactic methods
To evaluate the effectiveness of the different control methods, fruit samples from both treated and control orchards were taken to measure the level of pupae/kilogram infestation. During the experiment, four (4) fruit samples were selected for sampling at the beginning of the harvest season (P1), two (P2 and P3) during the peak harvest season and one (P4) at the end of the harvest season. The sampled fruits were brought back to the laboratory, weighed and incubated individually in boxes. The count was conducted from the third day after incubation to remove pupae and assess infestation levels.

The fruit fly population was expressed for the different methods in terms of the number of fruit flies caught per trap per day. Its value is the result of dividing the total number of flies caught (F) by the product obtained by multiplying the total number of traps (T) served by the average number of days (D) during which the traps were exposed. The formula is as follows:

$$-F.T.D. = \frac{F}{T \times D}$$

Or
F = Total number of flies
T = Number of traps maintained
D = Average number of trap days exposed in the field.

The infestation level and attack rates have been calculated according to the formulas below:

$$\text{- Infestation level (Pulps)} = \frac{\text{Number of pulps collected}}{\text{Total weight mangoes in kg}}$$

$$\text{Attack rate (\%)} = \frac{\text{Number of infested mangoes}}{\text{Total number of mangoes in the sample}} \text{X } 100$$

2.5 Statistical analysis
The data collected were analysed using Statistics and SPSS (Statistics Package for Social Science) software. The analysis of variance was used to compare the different treatments. The Student Newman-Keuls test was used to separate the averages at the 5% threshold.

3. Result and Discussion
3.1 Results
3.1.1 Level of infestation
In all treated plots in the three localities, the level of fruit infestation varies from 0.03 to 1 pupa per fruit. On the other hand, the number of witnesses varies from 5 to 17.77. In Trial 1, "Collection + Augmentorium", the average level of infestation was between 0.44 and 1 pupa per fruit. However, for Trial 2, " Ploughing + destruction", this average level of infestation was between 0.03 and 0.6 pupae per fruit. In contrast, in untreated or control orchards, infestation levels were higher than those of treated orchards. They ranged from 5 to 17.77 pupae per fruit on average.

3.1.2 Attack rate
In treated orchards, average fly attack rates ranged from 23.33 to 30% for Trial 1 "Ploughing + Destruction" and Trial 2 "Collection+ Augmentorium" respectively. Fly attack rates on control orchards are very high (70 to 80%) at all sites. Statistical analysis shows that there is a significant difference between the attack rates of treated orchards and those of control or untreated orchards. However, there was no significant difference between the trials of treated orchards in the three locations ($P=0.685$; $\alpha=0.05$).
Across all trials, mean attack rates in treated orchards were higher in the first year of the trial (2016) than in the second year (2017) (Fig1 and 2).

3.1.3 Catch index
The daily catch indices observed in the orchards treated in trials 1 “Ploughing + Destruction" and 2 "Collection + Augmentorium" are lower than those obtained in the control orchards in the three localities. The analysis of variance shows a significant difference between these indices

(P=0.00005 and α=0.05).

3.1.4 Catch period

In all orchards and in the three localities, high peak catches were observed between the second week of May and the third week of June each year. From the fourth week of June onwards, there was a gradual decline in catches to zero in the second week of July in 2016 and 2017 (Fig 3 to 8).

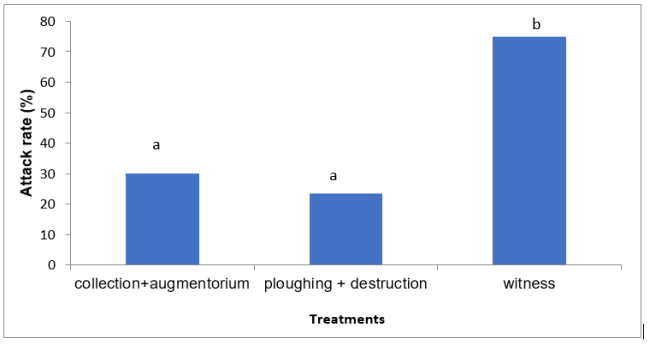

Fig 1: Average fly attack rate by prophylactic measures in 2016

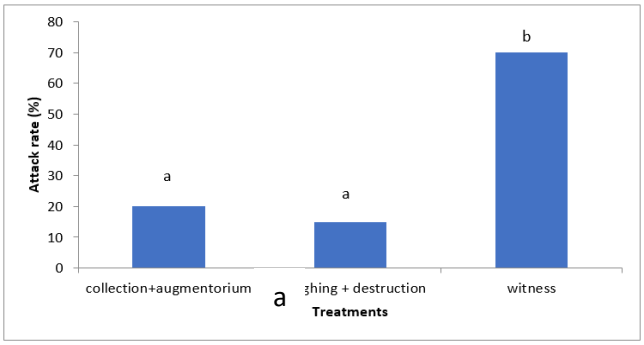

Fig 2: Average fly attack rate by prophylactic measures in 2017

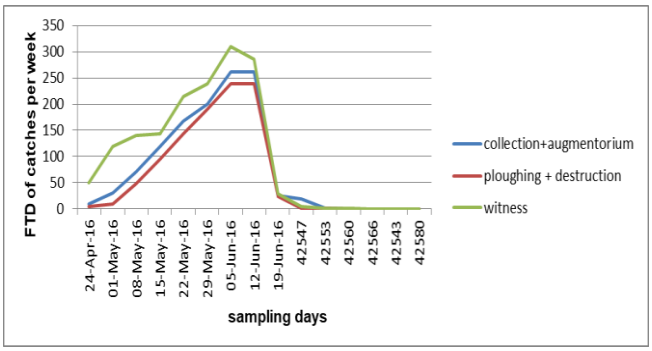

Fig 3: FTD of prophylactic methods in the locality of Korhogo in 2016

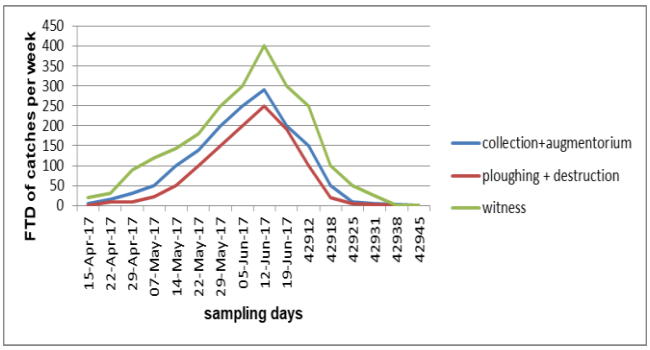

Fig 4: FTD of prophylactic methods in the locality of Korhogo in 2017

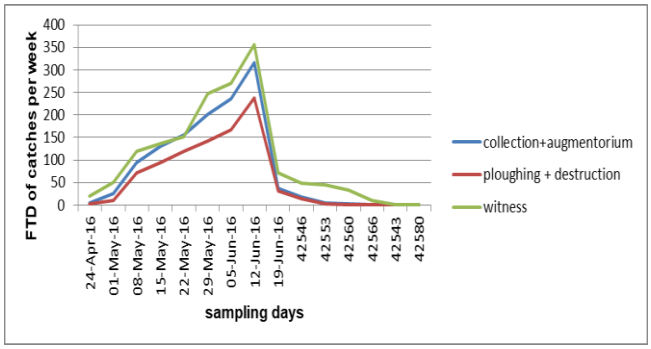

Fig 5: FTD of prophylactic methods in the locality of Sinématiali in 2016

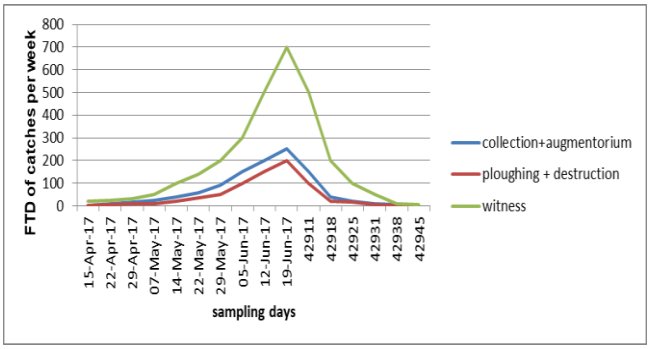

Fig 6: FTD of prophylactic methods in the locality of Sinématiali in 2017

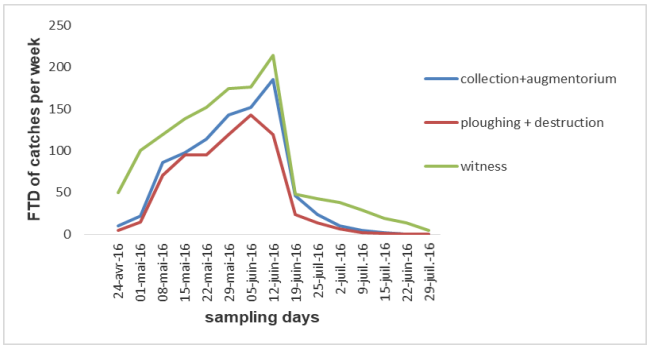

Fig 7: FTD of prophylactic methods in the locality of Ferké in 2016

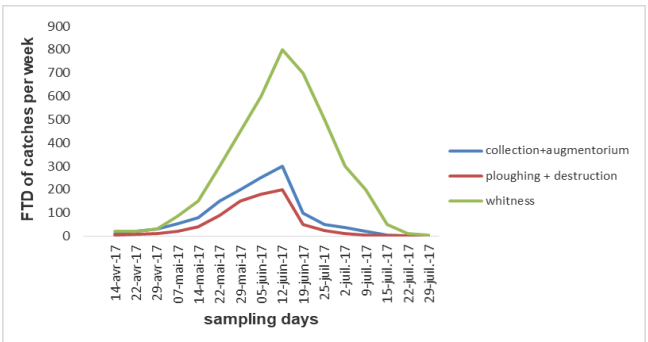

Fig 8: FTD of prophylactic methods in the locality of Ferké in 2017

4. Discussion

This study showed that prophylactic control based on ploughing the soil and destroying fruit by incineration recorded a 15% attack. This rate is the lowest compared to the control which was 70%. This low rate could be explained by the fact that with tillage, the fly's life cycle is

interrupted. Pupae are exposed to sunlight and predators. This resulted in a low emergence of flies inside the orchard. These results corroborate those obtained by Warlop (2003) [4], who indicates that biotic (parasitism, predation) or abiotic (frost, cold, heat) mortality factors result in a pupal reduction of more than 90%. According to Warlop (2003) [4], effective tillage will have enough impact on the following season, by removing a few more percentages. This method effectively reduced the attack rate from 23.33% to 15% for 2016 and 2017 respectively.

The low attack rate (30%) observed with the prophylactic method based on Collection + Augmentorium can be explained by the fact that the stung fruits collected each week and introduced into the augmentorium cause the destruction of the flies emerging inside the augmentorium by heat. In addition, there will be a multiplication of parasitoids within the augmentorium. Parasitoids fall through the augmentorium mesh to attack the eggs of flies laid on the fruit. The augmentorium thus prevents the re-infestation of the agroecosystem by a new generation of adult flies that emerge in the augmentorium. Studies conducted on the island of Reunion Island on farmers using augmentorium have shown that this technique is simple, effective, environmentally friendly and low in cost and time [5].

In terms of infestation, there was a variation in the rate of infestation of orchards resulting from the methods treated with "Ploughing + Destruction" and "Collection + Augmentorium", from the second year with 12.5% to 20% respectively and in the first year with 23% and 35% respectively. These results corroborate those from the work of Ouedraogo (2011) [6], who showed that infestation rates vary from one year to another in a mango orchard in Burkina faso.

According to the sampling period, it was found that the increase in fruit fly catches in treated orchards in May and June coincided with the period of high fruiting and heavy rainfall. This increase could be due to the natural life cycle of some flies such as *Bactrocera dorsalis*, whose population gradually increases during rainy periods. During this period, the relative humidity was high and the temperature was low. These results are similar to the work of White & Elson-Harris (1992) [7] who state that fly population levels increase with the onset of the rainy season. In addition, the use of sex pheromone traps would attract male flies over long distances. Vayssières *et al*. (2009) [8] attest that traps create epicentres of attraction for males, which are often converged over long distances.

5. Conclusion

At the end of this study, it appears that the prophylactic methods put in place represent effective means of controlling fruit flies in the short term. In addition to their proven effectiveness because this method reduces attacks from one year to the next by 7 to 10% and by 50 to 55% compared to control plots. They are also easy to install and less expensive. The study on prophylactic methods is a short-term voice, essential for producers. However, it should not be forgotten that the orchard is a largely unbalanced wooded environment. The concentration of mango orchards on thousands of hectares also favours the concentration of mango bio-aggressors. In such a monoculture context (generally no more than 2 varieties per orchard), with an environment reduced to the strict minimum (bare soil, trees), prophylactic methods can ensure 70% protection of mango orchards. This prophylactic technique must be part of a set of practices such as the management of the orchard environment to limit "edge effects" that generate a strong attraction of neighbouring populations, and a harmful re-infestation. It should also be noted that the technique of using augmentorium in fruit fly management is a tool for agro-ecological crop protection.

6. References

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