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# Field efficacy of IPM with mass trapping technique to control the Medfly "*Ceratitis capitata*" (Diptera: Tephritidae) in citrus orchards of Moulouya perimeter in North-East of Morocco

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**Abstract**
The mass trapping technique is the set and use of devices to attract insects to a killing agent. In Mediterranean regions, mass trapping has proved to be a powerful technique to control the Mediterranean fruit fly *"Ceratitis capitata"* (Wiedemann) (Diptera: Tephritidae) in citrus orchards. In Morocco, its application has recently increased due to the phytosanitary requirements imposed by the United States and Russia for citrus exports. This technique based on the set of a high density of traps, with an attractant and a toxicant agent, aims to capture the highest number of Medfly adults in the orchards. In 2016, 2017 and 2018, field trials were carried out in commercial clementine orchards (*Citrus clementina* variety Fina Berkane) in three localities of Moulouya Perimeter (Lamriss, Reggada and Slimania) to assess the effectiveness of introducing this technique in phytosanitary management programs against Medfly. The objective of this study is to evaluate an Integrated Pest Management Program including mass trapping technique (IPM+MT), a Program based solely on mass trapping, a Program based on a systematic chemical spray every seven days with a lambda-cyhalothrin molecule and a program control based on the conduct of the local growers. The devices used were the dry traps of 'FLYCAP MASS' type, and were hung at a density of 40 traps/ha. Our finding showed that plots that had undergone systematic chemical spray every seven days recorded an average rate of fruit infestation of 2.35%, and those with the Grower's conduct recorded a rate of 4.75%. Therefore, mass trapping, applied alone, did not reduce significantly the rate of fruit infestations by Medfly (3.66%), but once included in an integrated pest management program, it significantly reduced the rate of infested clementine fruits, to achieve a rate of 1.46%. Mass trapping should be taken as an element of a global approach of controlling Medfly in citrus orchards of Moulouya perimeter.

**Keywords:** Medfly, mass trapping, citrus, integrated pest management, infestation, captures

## Introduction
The Mediterranean fruit fly is one of the most devastative insect pests worldwide. Its ability to adapt to global ecological conditions and the increase of trade exchanges caused the rapid spread of the pest [1].

In 2016, the US phytosanitary authorities prohibited the import of citrus fruits from the region of Berkane, in Morocco, due to the detection of live Medfly larvae in a consignment from this region [2]. The mass trapping techniques have proved to be a powerful weapon in the control of Medfly, and its use has increased in Mediterranean basin countries [3, 4, 5]. The objective of this technique is to prevent crop damage by capturing high numbers of insect adults before the mating, egg-laying, or feeding period. The success of this method requires the combination of adapted attractive bait and a very efficient trap [6]. This technique is a substitute or complement to chemical spray in many countries, including Spain, Greece [3] and Tunisia [7]. However, the high costs of devices and attractants may limit the large-scale use of mass trapping [8]. But, the mass trapping technique has rapidly spread due to improving attractiveness and selectivity, and areas protected with this method are constantly expanding [9, 10, 11].

This study aimed to assess the effectiveness of introducing the mass trapping technique in the Medfly control programs in citrus orchards of Moulouya perimeter. Three control methods were compared in three localities (Lamriss, Reggada and Slimania) during three agricultural

seasons 2016, 2017 and 2018. These control programs were implemented as importing phytosanitary requirements of the USA, Russia, and China. For this purpose, three modalities were evaluated: T1: Mass trapping alone; T2: Mass trapping, monitoring, lambda- cyhalothrin-based treatment and orchard sanitation (IPM+MT); T3: Systematic chemical spray every seven days based on lambda-cyhalothrin and W: Conduct adopted by local farmers as Witness.

## Materials and Methods

### Study Area and Experimental Orchards

The present study was carried out on three citrus orchards planted with the "Fina Berkane" variety in the three localities of Lamriss (latitude 35°0'26.6" N, longitude 2°11'32.3" W), Slimania (34°57'56.9" N, 2°23'29" W) Reggada (34°56'3.9" N, longitude 2°13'47.3" W) at the Moulouya Perimeter. As Medfly damage occurs on fruits at early maturity, the choice of orchards for the study was based on the presence of the pest, using the results of monitoring traps and the period of receptivity of the variety to the insect punctures (period of earlier coloration and ripening). In each locality, an orchard has been selected and divided into four plots of two and a half hectares each, planted with the same clementine variety "Fina Berkane" of the same age and with almost the same fruit load. Treatments were randomly assigned to plots representing experimental units, while localities represented replicates. The distances between the selected plots were 100m apart to avoid any interference.

### Treatment modalities and traps type

The studied treatment modalities were as follows: The first treatment (T1) based on mass trapping alone, the second (T2) based on mass trapping associated with monitoring (trapping and visual), Lambda-cyhalothrin-based treatment and plot sanitation, the third one (T3) is based on systematic chemical treatment every Seven days based on Lambda-cyhalothrin, and the fourth one is a control based on the conduct adopted by the local growers farmers with no reasoned strategy. The traps were installed, in orchards, only during the period of susceptibility of the variety to Medfly attacks. This period starts around 30 September of each year of the study.

The traps used are of the FLYCAP MASS type, baited with a triple synthetic food attractant as active substance (0.19% 1,5-Diaminopentane 43.49% Ammonium Acetate (FFA), and 4.1% Trimethylamine (FFT)) with a Deltamethrin insecticide diffuser. This trap is a yellow plastic jar with a yellow lid and belongs to the category of so-called dry mass traps. The registered density of this trap in Morocco is 40 traps per hectare on citrus orchards. Traps were hung, on the South-East side of the trees, on a height of about 1.5 meters above the ground.

For the surveillance, "Maghreb Med" type traps have been used to monitor the dynamics of Medfly. These traps are presented in the form of an opaque white plastic jar with four lateral entry holes, baited with a selective male sexual attractant (Trimedlure), and an organophosphorus insecticide DDVP (Dichlorvos 2.2 Vinyl Dimethyl Phosphate), which has a persistence of action of 8 weeks. The attractant was changed once a month, while the DDVP capsules were removed and replaced by new ones every two months. In the center of each plot, a surveillance trap was set up on the southeast side of the tree canopy on a height of 1.5 m above the soil in all treatment modalities and the Witness. Insecticide applications in plots treated by the IPM+ MT program with lambda-cyhalothrin-based products were carried out using a trailed sprayer and are triggered immediately once the threshold of 0.5 flies per trap per day reached. The sanitation operation consists of the elimination and destruction of fallen fruits (on unattended trees and the ground), the removal of the sources of infestation (refuge plants), and the elimination of fruits left, during the previous season, on the trees.

### Evaluation of fruit infestations

For each treatment modality, the evaluation of the rate of punctured fruits was carried out on 20 trees of the same age and size, and with approximately the same fruit load. The observation carried out on 20 citrus fruits in the different cardinal orientations (N, S, E, W), i.e. 80 fruits per tree or 1600 fruits per plot. Surveyed trees were marked by a construction ribbon, fruits monitored in each tree, were identified by a label numbered from 1 to 80. The examination consisted of marking these fruits and examining them once every seven days and counting the number of infested fruits. Any fruit showing at least one puncture of *C. capitata as* counted as infested. Thus, the rate of punctured fruits was obtained by dividing the number of infested fruits by the total number of fruits diagnosed per tree and per plot.

$$\text{Rate of punctured fruits (\%)} = \frac{\text{Number of punctured fruits}}{\text{Number of examined fruits}} \times 100$$

The three modalities have been set since August 15th, notably for sanitation and chemical treatments associated with the monitoring traps. However, for mass trapping, it was only installed on September 30th, before the appearance of certain fruits receptive to Medfly punctures (coloration and beginning of ripening).

The percentages of punctured fruit per week, per year, per location and treatment modality, were used as the basis for comparison of each treatment modality tested. The data obtained underwent analysis by a generalized linear model test (GLM) followed by Tukey's HSD test (Honestly Significant Difference) to separate the means. All calculations and statistical analyzes were performed using SPSS version 25 software.

## Results and Discussion

### Meteorological data

The study area belongs to Moulouya Perimeter with a Mediterranean type climate and a semi-arid dominance. The average annual rainfall is 300 mm with irregular distribution in time and generally concentrated in the period from December to April. Average year temperatures vary between 5.2 and 18.7 degrees in winter and 18.5 and 31 degrees in summer (Fig. 1)

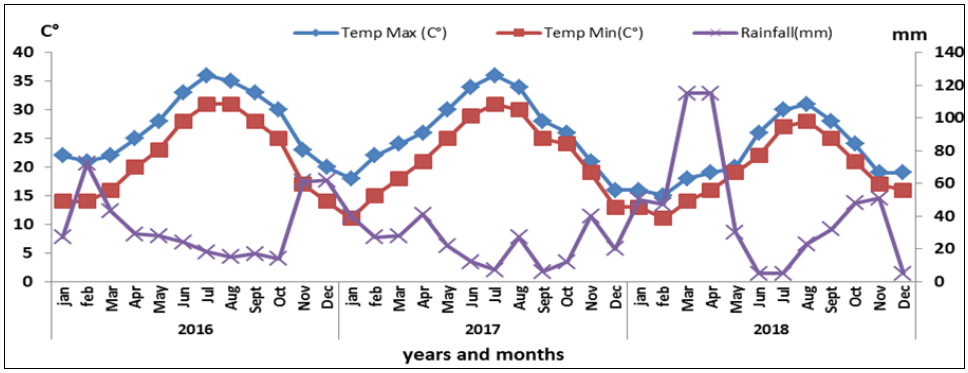


**Fig 1:** Evolution of Temperatures and Rainfall during the three years of study in Moulouya Perimeter

**Evaluation of fruit infestation on trees**

Out of 1600 fruits observed/plot on the trees of each plot on a regular basis (every Monday), the mean percentage of punctured fruits changed from 0.43% in all three treatment modalities against 0.6% for the witness, at the beginning of fruit coloration (week of October 10-17) to a maximum of 2.76% and 5.2% recorded for the averages of the treated plots and the witness towards the end of the study period for the different localities and years (December 12-19).

From the third survey (last decade of November) a sharp increase in fruit infestation rates was recorded, reaching 3.8% in plots treated by mass trapping alone, 1.6% in plots treated by mass trapping, chemical treatment with lambda-cyhalothrin and monitoring, 2.5% in plots systematically treated every seven days with lambda-cyhalothrin, compared to 5.2% recorded in the Witness (Fig. 2). The percentages of punctured fruits by Medfly continued to increase slightly to reach a maximum towards the beginning of December (28 November - 5 December), i.e., 4% in plots treated by mass trapping alone, 1.7% in plots treated by mass trapping, chemical treatment with lambda-cyhalothrin and monitoring, 2.6% in plots systematically treated every seven days by lambda-cyhalothrin, compared to 5.2% recorded in the Witness (Fig. 2). This rate stabilized three weeks before the end of harvest. This is probably due to the phenomenon of regulating the number of eggs deposited in the same fruit by secretion of a marker pheromone, which has a repellent effect for a new act of oviposition. This phenomenon has been observed in several species of Tephritidae [12, 13]. This increase can be explained by the high level of Medfly populations recorded during this period, which is probably due to the maturity and receptivity of the fruits. In general, the infestation rate recorded was significantly lower, throughout the study period, in all plots with treatment modalities compared to the Witness (Fig. 2 and Fig. 3) regardless to locations.

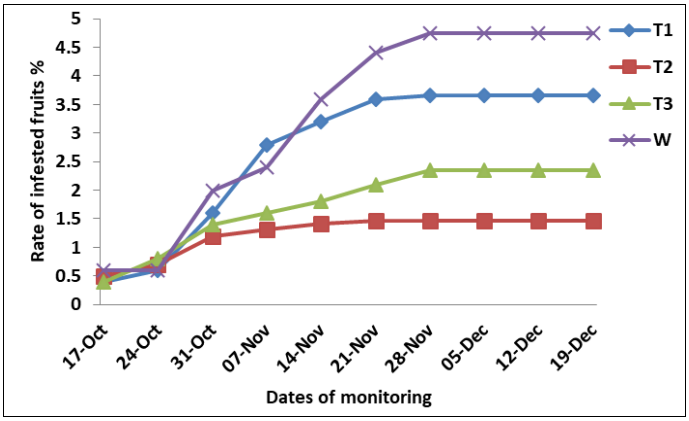


**Fig 2:** Evolution of the rates of punctured fruits for each treatment modality

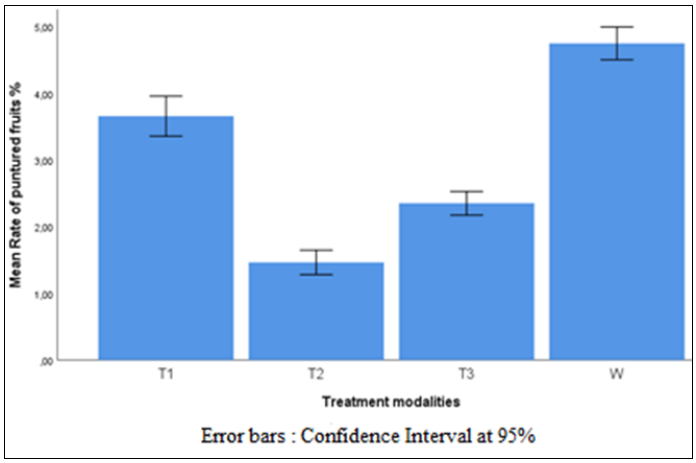


**Fig 3:** Percentages of infested fruits by treatment modality in all plots studied

Comparison of the means of fruit infestation rates in the plots studied and the witness based on the generalized linear model revealed a very highly significant difference (P=0.000<0.05) between the rate of infested fruits in all treated plots and the witness plot (Table.1). Also, comparison of the means of the infestation rates of the different modalities two by two revealed the presence of a highly significant difference between all treatment modalities. Also, three distinguished homogeneous sub-sets were separated and every sub-set was represented by one of the three modalities (Table.1).

**Table 1:** Comparison of means of rate infested fruits for all treatment modalities

| | Treatment modalities N | | Sub-assembly | | | |
|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 |
| **Significant difference of B Tukey [a,b]** | T2 | 27 | 1,4652 | | | |
| | T3 | 27 | | 2,3526 | | |
| | T1 | 27 | | | 3,6601 | |
| | W | 27 | | | | 4,7526 |

Calculation based on observed averages. The error term is the mean square (Error) = 0,168.
a. Uses harmonic mean sample size = 27,000.
b. Alpha = 0,05.

During the three years of the study, in all three localities, the treatment T2, based on an IPM+MP, allowed maintaining Medfly punctures at very low levels compared to the other modalities. Thus, trapping combined with the other practices of integrated management of this pest gives better results compared to the treatment (T1) based on mass trapping alone (Fig. 4 and Fig. 5). Mass trapping alone does not control populations nor maintain them at desired levels, especially for fruit to be exported to Russia and the USA that requires rate of infestation lower than 1% before authorizing citrus fruits to be processed in packinghouses.

Regardless of locations (Lamriss, Reggada and Slimania), the treatment (T3) scheduled systematically every seven days maintained the percentage of punctured fruit at a lower level compared to the Witness and to T1, but at a higher level than that obtained in the treatment T2. Thus, In order to benefit from the effectiveness of Mass Trapping, it must be a part of an overall approach of integrated pest management of the Mediterranean fruit fly. The method T2 had limited chemical sprays to four interventions, in contrast to T3, in which eight treatments were applied and with lesser results in terms of reducing the number of fruit punctured. In Spain, Up to eight sprays can be applied in citrus orchards to control medfly in a season [14]. However, performing chemical sprays does not systematically guarantee that fruit losses will be avoided or reduced to desired thresholds. Alonso-Muñoz *et al*. [15] demonstrated that the percentage of fruits punctured or presenting Medfly larvae is higher than 2% in plots having received a localized chemical treatment compared to the plot treated by mass trapping. In northeast Argentina, a trial carried out during 2001 to compare two types of traps with conventional spray control revealed the similarity in terms of Medfly control between Mass Trapping and chemical control [16]. In South Africa, studies carried out showed the effectiveness of mass trapping in maintaining Medfly populations at an economically tolerable threshold. Also, if mass trapping has been installed on a large scale over large areas, it can keep areas free of *Ceratitis* [17]. The same results were reported in recent several other studies [18, 19, 20, 21].

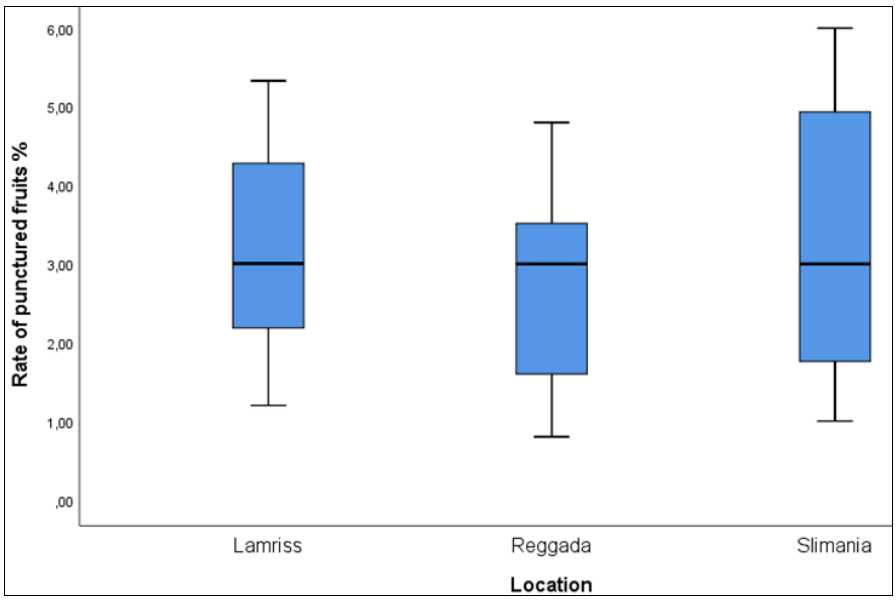


**Fig 4:** Percentages of infested fruits by locality for all treatment modalities during the three years of the study

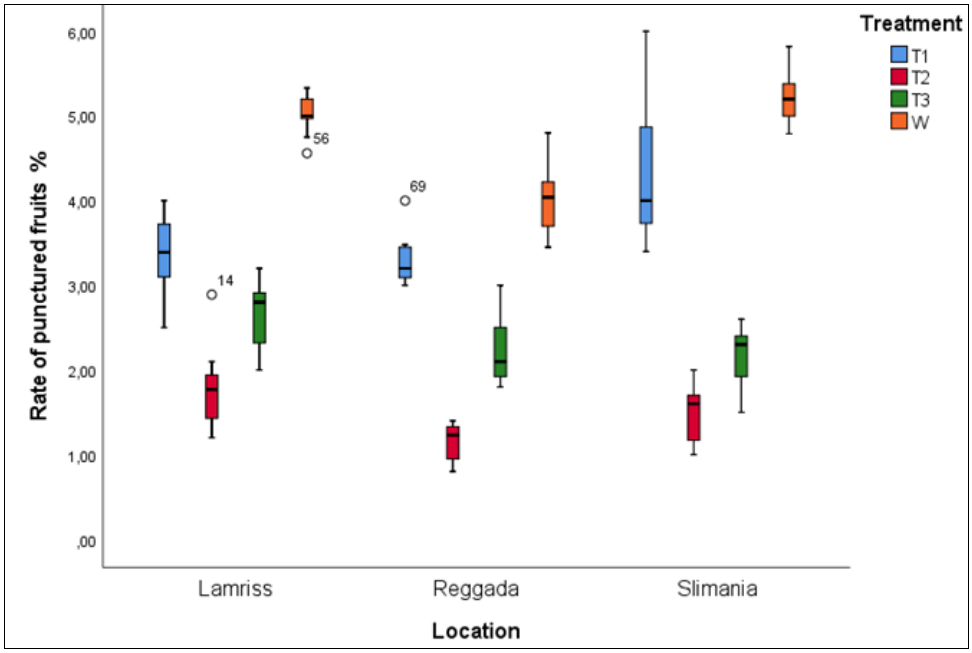


**Fig 5:** Percentages of infested fruits by treatment modality per location in all plots studied during the study period

## Conclusion

This work confirmed the importance of mass trapping technique for the control of the Mediterranean fruit fly in citrus orchards in northeastern Morocco as a method to be integrated as part of phytosanitary management strategy against Medfly. The methods tested help to produce healthier fruit in that they reduce pesticide applications, which is very important due to the growing interest in the production of citrus fruit for fresh consumption. This study showed the importance of the mass trapping technique combined with integrated pest management techniques for fruit fly control in citrus orchards in the Moulouya perimeter conditions, compared to chemical spraying alone. However, for further details, an economic evaluation of this technique is recommended in order to determine, evaluate and optimize control on a larger scale. The integration of the mass trapping technique into integrated protection methods is a strategic choice, which encourages the harmonious use of available control measures in pest management, limits the number of chemical interventions and gives priority to environmentally friendly and economically justified control methods. Mass trapping will reduce the number of treatments, especially those applied near pre-harvest, which increase the risk of insecticide residues.

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