# The status of medfly and IPM practices based on case studies in Italy

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***Abstract***

**Mediterranean fruit fly (medfly) is considered one of the world's most destructive pest. In recent years, medfly has expanded its distribution in temperate areas. With global warming, it is expected that the geographic distribution of medfly will expand to higher latitudes and its pest status in the areas that currently have low population levels will change. Indeed, in recent years in Italy, medfly began to appear as stable populations with high densities in areas where it was not previously considered a major pest. In the present paper, the status of medfly and IPM (Integrated Pest Management) practices were investigated in two areas of central Italy. Within each area, three farms were selected. The investigation allowed us to define the spatio-temporal dynamic of medfly in each farm and the key host species for overwintering; to evaluate the pest status for various fruit species and cultivars; to establish the range of pesticides and other means used for medfly control; and to calculate the costs related to relevant medfly IPM practices.**

**Keywords:** *Ceratitis capitata*, spatiotemporal dynamic, overwintering, trap monitoring, mass trapping, insecticide spray application, sanitation

## INTRODUCTION

Mediterranean fruit fly (medfly), *Ceratitis capitata* (Diptera: Thepritidae), is considered one of the world's most destructive pest. Its economic importance is increasing due to its invasion of new geographical areas. It has high dispersive ability and a large host range. Indeed, it is able to infest the fruits of over 300 species of plants (Morales et al., 2004; Meats and Smallridge, 2007; CABI, 2021). In recent years, medfly is expanding its distribution in temperate areas. With global warming, it is expected that the geographical distribution of medfly will expand to higher latitudes and its pest status in the areas currently with low population levels will change (Giglioli et al., 2022). Indeed, in recent years in Italy, medfly began to appear as stable populations of high densities in areas where it was not previously considered a major pest (Zanoni et al., 2017).

In this contribution, the status of medfly and IPM practices were investigated in two areas of central Italy in which traditionally the pest was not considered a key pest of peach and other fruit crops. Within each area, 3 farms were selected. A detailed characterization of the farms was carried out. The following aspects were studied in 2020 and 2021: host fruit phenology; determination of annual patterns of medfly immature stages and adults; identification of medfly overwintering resources and assessment of their capacity; collection of socio-economic background information. The investigation allowed us to define the spatio-temporal dynamic of medfly and the key host species for overwintering; to evaluate the pest status for various fruit species and cultivars; to establish the range of pesticides used for medfly control; to calculate the costs related to the implementation of most common IPM fruit fly practices. The information gathered under these case studies will be of broader relevance to other European regions and useful in optimizing the application of IPM tools against medfly.

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## MATERIALS AND METHODS

### Study areas: characterization of the farms and host fruit phenology

The investigations were conducted during 2020 and 2021. Six farms were selected, 3 farms (Farms A, B, and C) in the territory of the municipality of Campomarino (Molise region) and 3 farms (Farms D, E, and F) in the territory of the municipality of Paliano (Latium region). The 2 study areas (Campomarino and Paliano) are separated by approx. 160 km; within each study area, farms were separated by a distance of 1.5 to 8 km. For each farm, the location of all relevant host plants and cultivars, as well as their phenology, were recorded.

The Campomarino study area is located in a coastal area near the Adriatic Sea. The territory is largely agricultural. The selected farms are multivarietal conventional fruit farms. The three farms have the following characteristics. Farm A (45 m a.s.l.): approx. 3.8 ha of fruit orchards composed of peach (2.9 ha), apple (70 trees), plum (0.1 ha), apricot (0.7 ha), pomegranate (35 trees), and sporadic plantings of fig, pear and prickly pear. Farm B (24 m a.s.l.): approx. 13.5 ha of fruit orchards composed of peach (2 ha), apricot (50 trees), plum (50 trees), and grape (11 ha). There is a garden in which are present persimmon, apricot, fig, apple, pear, and citrus trees. Farm C (25 m a.s.l.): approx. 3.2 ha of fruit orchards composed of peach (1.2 ha) and plum (2 ha). There are also sporadic plantings of fig and citrus.

The Paliano study area is located in a hilly area. The territory is largely agricultural with mainly horticultural crops, vineyards and olive orchards. The selected farms are two multivarietal conventional fruit farms (Farm D and F) and one organic farm (Farm E). The three farms have the following characteristics. Farm D (250 m a.s.l.): approx. 27 ha of fruit orchards composed of peach (16.2 ha), kiwi (8.26 ha), apricot (1.08 ha), apple (0.78 ha), and pear (0.84 ha). In the site, there are also sporadic plantings of persimmon, cherries and some grape plants. Farm E (260 m a.s.l.): approx. 1 ha of fruit orchard composed of peach (0.38 ha), apple (0.15 ha), plum (0.1 ha), pomegranate (0.16 ha), blackberry and goji berries (0.1 ha). Farm F (290 m a.s.l.): approx. 1.5 ha (decreased to 0.6 ha in 2021) of fruit orchard composed of peach (1.2 ha in 2020 season), apple (0.2 ha), pear (0.1 ha), and plum (0.1 ha). Before the beginning of 2021 season, the farmer removed 0.9 ha of peach orchards.

In the study areas, the presence of fruit in the field, useful for medfly development, begins in June with early apricot species (in Farm A, B, and D) and continues throughout the summer season, mainly with the various peach cultivars present in all farms. The apple trees (mainly present in the Farms A, D, and F) represent the last available fruit (Figure 1). Non-harvested apples can remain in the field until spring of the following season. In addition, sporadic orange and prickly pear plantings may host medfly infestations even in winter.

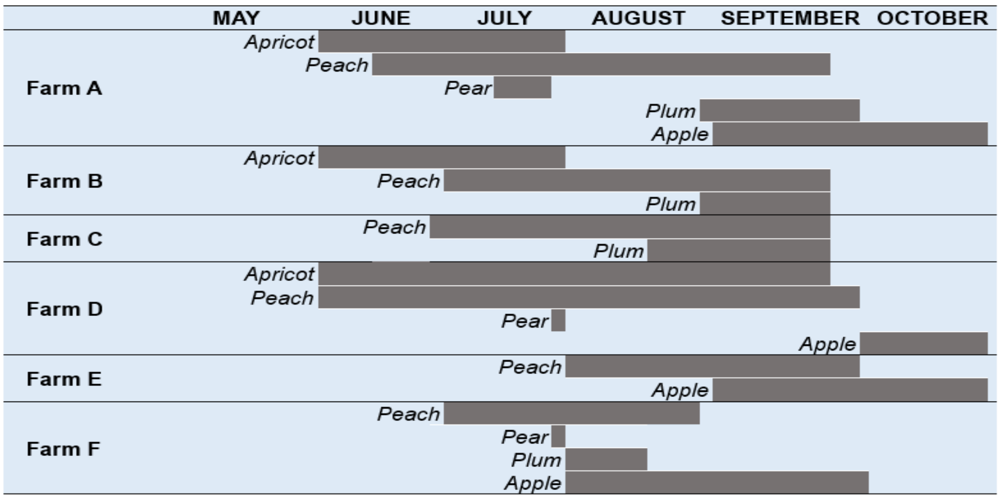


Figure 1. Seasonal medfly host availability and maturation period of the fruits.

**Medfly population assessment**

The activity of medfly adults was monitored using white delta-type Jackson traps baited with a male-targeted trimedlure dispenser (Fasmi, Cercemaggiore, Campobasso, Italy) and Decis® traps (Bayer CropScience, Milan, Italy) with a female-targeted dispenser impregnated with ammonium acetate, chlorohydrate trimethylamine, and 1,5-Diamineopentane. Trimedlure dispensers were replaced every 4 weeks. The attractant in Decis® traps was replaced every 4 months. The monitoring period lasted two years (2020-2021). Traps were installed with a density of 1-2 per hectare, to cover all the species present in the farms and the various cultivars with similar fruit ripening periods. The traps were set in pairs (one Jackson trap and one Decis® trap) at a distance of about 10 m between them. In particular, the number of pairs of traps set was: 12 in Farm A, 8 in Farm B, 7 in Farm C, 19 in Farm D, 6 in Farm E, and 7 in Farm F. Medfly caught in the traps were removed and counted on a weekly basis from May to December and twice a month from January to April.

The larvae activity was evaluated during the harvest period. The cultivars were categorised into 3 seasonal host categories in relation to the fruit ripening period: early summer (June-July), summer (August-Sept.), autumn/winter (October and later). At the harvest period of each seasonal host, samples of 50 fruits were collected from the trees and from the ground. Infestation assessment was conducted through dissection and visual inspection of the larvae inside the fruit. After sampling, the fruits were stored at room temperature in the laboratory to allow the larvae to develop and make them easily visible at the dissection, which took place after 5-40 days.

To estimate the "overwintering" capacity of the resources in each farm, two surveys were carried out: (1) Estimation of the area covered by the "winter fruits" and the number of trees of these fruit species present on-farm. "Winter fruits" refer to species with fruits remaining in the field after harvesting during the winter period (Dec. to Feb.) and that could host the pre-imaginal medfly stages. (2) For each "winter fruit" species, two samples of fruits were collected (in variable numbers according to field presence). From one sample (50% of collected fruits), the fruits were dissected and reviewed for overwintering larvae. The second group was stored at room temperature in the laboratory in order to record emerging, pupating larvae. This activity was carried out in mid-December, the second half of January and at the end of February.

**IPM practice costs**

The assessment of the costs of various IPM interventions was evaluated by taking into consideration the cost of materials and the labor (hours of work × unit labor cost). For the estimation of labor cost, the official cost of a contractor (National Collective Contract, Level 5 agro-mechanical operations), which includes costs for the use of agricultural equipment/ tractor for the same time unit, was used.

The cost of the IPM interventions (for various brands commonly used in Italy) was assessed as follows: (1) pest monitoring, cost of 2 traps and baits serviced weekly for 3 months; (2) mass trapping, cost of 100 traps and baits for 3 months (1 check in 3 months); (3) orchard sanitation, collected fruits from 1 ha; (4) bait spray or pesticide application, 1 application for 1 ha. The total hours of work unit for the orchard sanitation were estimated by performing 6 repetitions of sanitation in an area of 1000 $m^2$ (3 repetitions on apple orchards and 3 on peach orchards).

## RESULTS AND DISCUSSION

**Medfly population assessment**

During 2020 in the Campomarino area, the first capture of medfly adults was recorded on 13 July in all farms from peach (early summer and summer) orchards. Peak catches were recorded during the end of September in peach orchards from Farms B and C and on mixed trees (figs and one tree of persimmon) from Farm A. The last capture (late December) was generally performed on peach, while in Farm C this was conducted on multi varietal orchard. A total of 25,109 medflies (8,602 females and 16,507 males) were trapped in 2020 (Figure 2).

Similar data were recorded in 2021. The first captures were recorded on the last week of July in apricot orchards in Farms A and B. The highest number of catches was recorded in mid-September in mixed trees (fig and persimmon) and apple orchards in Farm A and in peach orchards in Farms B and C. In Farm C, very high numbers of catches (more than 650 males/trap/week) were recorded in summer peach, probably due to the non-harvesting of fruits damaged by a hailstorm in mid-August. The last capture was performed in the first week of December with few catches distributed among the different farms. A total of 14,629 medflies (2,215 females and 12,414 males) were trapped in the 2021 season (Figure 2).

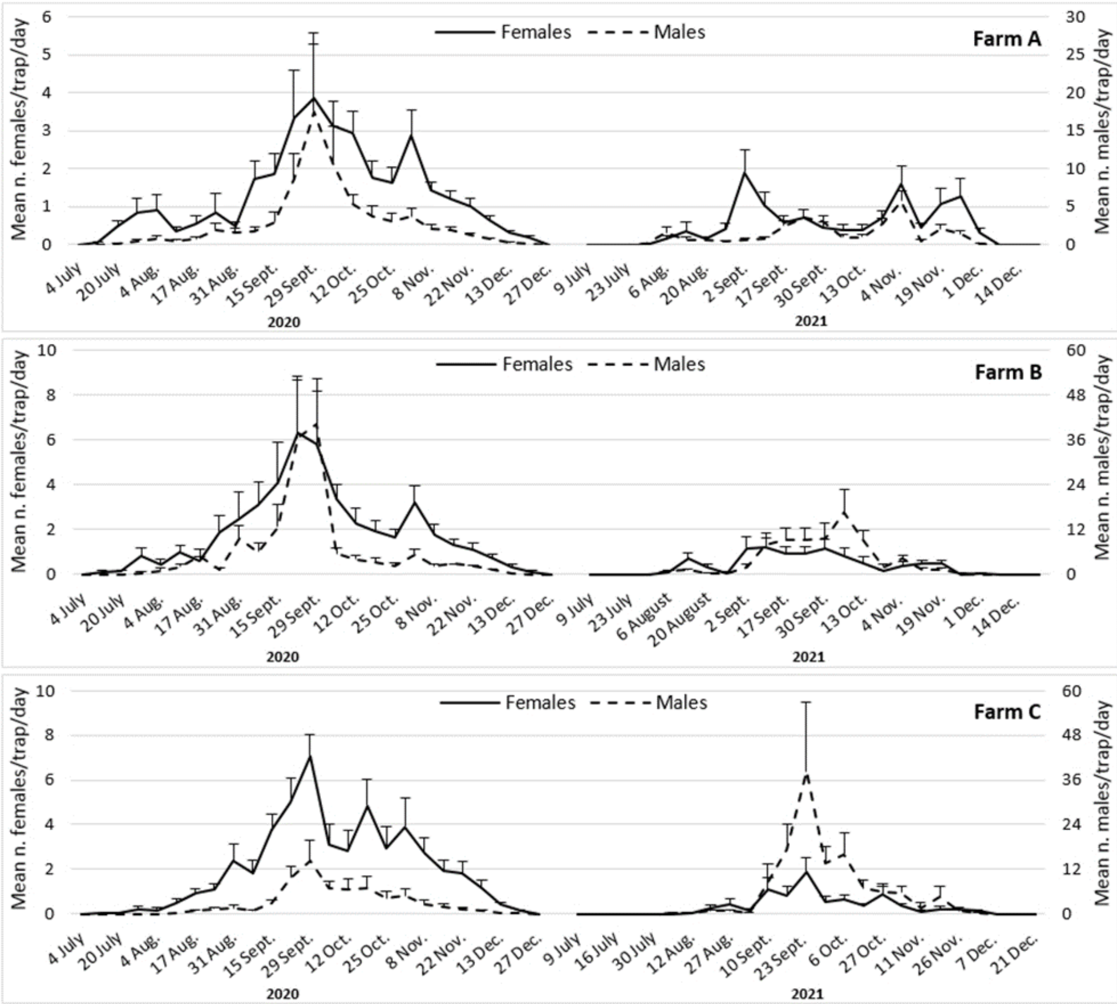


Figure 2. Medfly catches of females in Decis traps and males in Jackson traps, expressed as the mean number of flies per trap per day (± SE), in Campomarino area farms.

In the Paliano pilot site during 2020, the first capture of medfly adults was recorded in the second half of July in peach orchards of all farms, with the highest number of catches recorded between the last weeks of September and the first week of October. Another peak occurred in Farm F at the end of November. This could be related to the non-harvested apples in the orchards, usually done at the end of September. The last captures were performed on 4 November in Farm E and in the first days of December in Farms D and F. A total of 6,304 flies (1,127 males and 5,177 females) were trapped in 2020 (Figure 3).

During 2021, the first capture of medfly adults was recorded on 2 August in a mixed orchard in Farm D and in an apple orchard in Farm F. The first capture in Farm E was recorded on 8 September. In all farms, peak catches were recorded between the end of September and the first week of October and the last capture at the end of November. A total of 3,389 flies (1,106 males and 2,283 females) were trapped in 2021 (Figure 3). For 2021, if compared with 2020, we recorded a delayed presence of adults in the field (2 to 6 weeks delay) and a lower population density in August/early September. This could be caused by the absence of early fruit (ripening in June-July) due to a late frost at the end of April, which totally compromised fruiting. Relative larval activity, no damage was found in the fruits sampled in the farms of Paliano area, despite the presence of adults being recorded in both seasons.

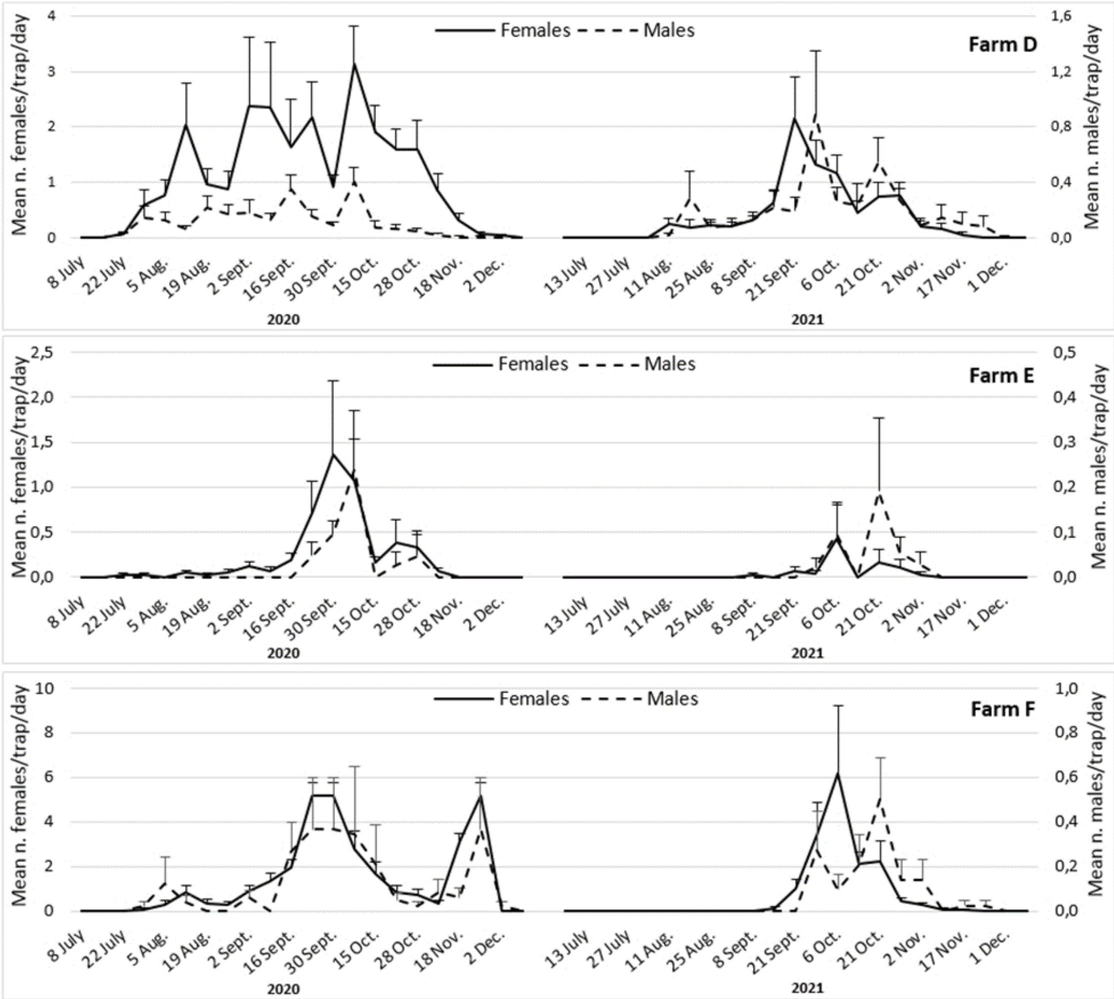


Figure 3. Medfly catches of females in Decis traps and males in Jackson traps, expressed as the mean number of flies per trap per day (± SE), in Paliano area farms.

In the Campomarino area, the first fruit damage in 2020 was found in early summer peach on 20 July, while in the 2021 the same fruit category did not report damage. The first infested fruits in 2021 were found on 2 September in summer peach. The summer peach categories in both years showed the highest damage rates, with more larvae sampled in 2020 than in 2021. Apple was the latest host category (generally harvested in late September-early October) present on the farms (in particular in Farm A). Here damage was found in both years, with the highest infestation present in 2021, despite the presence of fewer adults.

Table 1 shows the results of fruit damage sampling in the Campomarino pilot area farms, reporting the percentage of infested fruits and average number of larvae per fruit. The seasonal host categories in which no infestation was found have not been reported.

Table 1. Fruit damage (expressed in percentage) and mean number (±SE) of larvae per infested fruit in 2020 and 2021 seasons.

| Date of sampling | Seasonal host category | Farm | Cultivar | Damage by *Cc* (%) | | Mean number of larvae (±SE) | |
|---|---|---|---|---|---|---|---|
| | | | | Fruit on tree | Fruit on ground | Fruit on tree | Fruit on ground |
| 20 July 2020 | Early summer peach | Farm A | Big Top | 2 | 6 | 5.0 | 4.3±1.3 |
| 20 July 2020 | Early summer peach | Farm B | Big Top | 4 | 0 | 3.0±1.0 | 0 |
| 31 August 2020 | Summer peach | Farm A | Baby Gold 9 | 4 | 14 | 4.5±2.5 | 7.9±2.5 |
| 7 September 2020 | Summer peach | Farm B | Jungerman | — | 22 | — | 7.7±2.5 |
| 7 September 2020 | Summer peach | Farm C | Baby Gold 9 | 8 | 18 | 6.8±2.2 | 5.8±1.4 |
| 29 September 2020 | Summer apple | Farm A | Fuji | 2 | 6 | 1.0 | 8.7±1.8 |
| 2 September 2021 | Summer peach | Farm A | Baby Gold 9 | 2 | 4 | 5.0 | 1.5±0.5 |
| 10 September 2021 | Summer peach | Farm B | Jungerman | 0 | 4 | 0 | 3.0±1.0 |
| 7 October 2021 | Summer apple | Farm A | Fuji | 20 | 2 | 9.2±1.8 | 6.0 |

In the Campomarino area, Farm A and B have “winter fruits” which could host the pre-imaginal medfly stages; in the Paliano area, all farms produce “winter fruits”.

In Farm A, 70 apple trees were present. During the December 2019 inspection, apples were found on the tree and on the ground, while in the inspection of late January 2020 no fruit was found. From collected fruits in December, the first dissection detected no larvae, while after the incubation period (conducted outdoor in the same area of the farm) 5 pupae emerged in spring (15 April) from 50 fruits. Similar data were collected in winter 2020-2021, with infested fruit found in the December inspection and no fruits found in January 2021.

Farm B had 2 apple, one persimmon, and 6 citrus trees. In the inspection of late December 2019 no fruits were present, while in December 2020, few fruits were counted on trees and on the ground. From collected fruits, no larvae or pupae were found. A second inspection was conducted in late January. The only fruits in the field were citrus on the tree, and also in this case no larvae or pupae were found in the collected fruits.

In Farms D (about 2000 apple trees) and E (95 apple trees), a few apple fruits were found only in the December checks (2019 and 2020). In both years, neither larvae nor pupae were detected.

In Farm F, about 400 apple trees were present. During the December 2019 inspection, several apples were observed on the trees and on the ground. From collected fruits, the first dissection detected 25% damage, and after the incubation period of 80 fruits, 43 larvae pupated in January. A second inspection was executed in January 2020. From collected fruits, the first dissection detected 4% damage, with dead larvae inside fruits. After incubation of 80 fruits, neither larvae nor pupae were detected. In the February 2020 inspection, no fruit was found. During the winter 2020-2021, several fruit on trees and on ground were observed in the December, January and February surveys, but no medfly damage was observed.

In the surrounding area of the Campomarino farms, prickly pears and some citrus trees were present. From fruit collected in the two winter periods, no larvae were found.

In the two areas of central Italy, data on medfly adult captures showed a similar trend, with few adults individually caught in traps during July, a general increase in August with population peak reached in late September-early October. From January to early-July adults are not detected in the traps, despite the presence of host fruits in the period May-June and suitable temperatures for the medfly.

Larvae were found in the Campomarino area from late July to October, mainly in peach cultivars, with an increased level of infestation in the late maturing cultivars and on apple trees. The lack of damage in some Paliano area samples could be due to the low population density of the medfly – below the detection sensitivity of the protocols used.

In both areas, active larvae were found on apple trees in December but not in January and February. In farm F, some larvae were found in January, but these were dead. However, few pupae emerged in April from apples stored outdoors at Campomarino. Papadoupolos et al. (1996, 2001) assumed that only a small number of adults, overwintering in apple fruits, emerge in the spring and that, due to the very low population density, the traps are unable to detect the few adults present. Our data confirmed that the larvae of medfly can remain in apple fruits during the winter, but there is high insect mortality, probably due to cold temperatures.

**IPM practices costs**

In the experimental farms, medfly infestations are managed only with cover spray insecticide treatments. No-control techniques have been used in recent years in Farm E. The Table 2 summarizes the spray applications carried out in the 6 farms over the two years and the cost per hectare in relation to the number of treatments and products used.

Table 2. Number of pesticide spray application carried out in experimental farms divided by year and by active ingredient used and estimation of cost of treatments per hectare.

| Active ingredient | Farm A | | Farm B | | Farm C | | Farm D | | Farm E | | Farm F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Deltamethrin | 1 | 4 | 2 | 5 | 3 | 3 | 1 | - | - | - | 1 | - |
| Emamectin benzoate | - | - | - | 2 | - | 2 | - | - | - | - | - | - |
| Etofenprox | 2 | 1 | 1 | 1 | - | - | 1 | 2 | - | - | - | - |
| Fosmet | - | - | - | - | 1 | - | 2 | 1 | - | - | 1 | - |
| Indoxacarb | 1 | 1 | 2 | 1 | - | - | - | - | - | - | - | - |
| Lambdachyhalotrin | - | - | - | - | - | - | 1 | 1 | - | - | - | - |
| Total cost (euro $ha^{-1}$) | 272.8 | 308.4 | 312.3 | 601.0 | 197.4 | 368.2 | 346.4 | 302.4 | 0 | 0 | 121.8 | 0 |

The total cost incurred in the two-year period presents at least two scenarios: a scenario of cost stability (about 300 €) in two farms (A and D) and a scenario of variable, highly increasing cost, in two farms (B and C). Apart from the technical opportunity about the intensity of the spray application, from an economic point of view the cost variability is not a favorable scenario.

In Table 3 are reported costs calculated for some standard monitoring and control tools currently available for Medfly control, including those applied in the surveyed farms.

From an economic point of view, the lower cost of spray application makes it a rational choice to be followed instead of other interventions, even more when considering the wide spectrum of effectiveness of the practice. Pest monitoring was not carried out by the selected farms. Such an approach, that has limited costs, can have an economic return by reducing the number of spray applications and by optimizing them only where really needed. Through monitoring it would be possible to identify areas where techniques such as mass trapping could be applied.

Both mass trapping and sanitation, if considered as a single practice, are beyond economic feasibility, although from the point of view of the environmental sustainability they have some strengths; this is even more true in the case of integrating more tools together, whose costs are not feasible compared to the only spray application. To make mass trapping a realistic option, its application should be concentrated in period of the season and part of the farm (e.g. only in orchards where the first flight of adults begins) in order to generate a general effect of population suppression on the remaining orchards throughout the season.

The variability of the time needed for manual sanitation after harvesting time strongly depends on the number of fruits not harvested, thus ultimately on the accuracy of harvesting. Trials in the experimental farms showed that, on average, for the sanitation of 1000 $m^2$, one person takes 85±41.7 (± ES) minutes to collect the fruits from the trees (mean of 611.7±267.6 fruits) and 193.5±77 min to collect the fruits from the ground (mean of 2749.7±579.6 fruits). The estimated average time taken by a person for 1-ha sanitation, used to calculate the economic costs, is 46 h.

Table 3. Evaluation of the IPM intervention costs for one hectare of orchard.

| IPM interventions | Type of trap + attractant/ Active ingredient (if pesticide) | Cost of the material (euro) | Total cost including labor (euro) |
|---|---|---|---|
| Pest monitoring | Tephri trap + Trypack | 11.5 | 55.4 |
| | Decis trap | 7.9 | 51.8 |
| | Delta trap + Trimedlure | 23.2 | 67.1 |
| | Trak-ala + Trimedlure | 25.4 | 69.3 |
| Mass trapping | Tephri trap + Trypack | 575.0 | 737.2 |
| | Decis trap | 395.0 | 557.2 |
| Orchard sanitation | | 20.0 | 647.3 |
| Spray application | Affirm (Emamectin benzoate) | 107.1 | 127.4 |
| | Decis EVO (Deltamethrin) | 17.5 | 37.8 |
| | Karate zeon 1.5 (Lambdacyalotrin) | 42.5 | 62.8 |
| | Steward (Indoxacarb) | 59.2 | 79.5 |
| | Spada 200EC (Fosmet) | 63.7 | 84.0 |
| | Trebon (Etofenprox) | 57.5 | 77.8 |
| Spray application with bait | Affirm (Emamectin benzoate) + Nu Bait | 101.6 | 111.7 |
| | Decis EVO (Deltamethrin) + Nu Bait | 56.7 | 66.9 |
| | Karate zeon 1.5 (Lambdacyalotrin) + Nu Bait | 69.2 | 79.4 |
| | Steward (Indoxacarb) + Nu Bait | 77.6 | 87.7 |
| | Spada 200EC (Fosmet) + Nu Bait | 79.9 | 90.0 |
| | Trebon (Etofenprox) + Nu Bait | 76.7 | 86.9 |

In spite of the sure benefits that sanitation can provide in lowering the next pest generation, the cost seems excessive and alternative solutions must be thought of, such as the accumulation of unharvested fruits on the ground and their mechanical destruction during tillage operations. This approach, however, cannot be applied in orchards with grass cover.

## CONCLUSIONS

The results of this work allowed us to evaluate the status of the medfly in low-infested areas in central Italy. In these farms, medfly adults are caught in traps from the end of July to December, with more larval activity in August-September. This population dynamic makes most fruit species harvested from August susceptible of economic damages, represented by peaches and apples in the investigated farms.

As a consequence, control measures against medfly were undertaken by all but one farm (organic). Given the costs of different IPM interventions, farmers prefer to carry out insecticide sprays only. Monitoring, which was not carried out by the selected farms, could also reduce insecticide spray application costs, as these would be timed and localized only when and where really needed. The application of pest prevention and monitoring techniques was included in Italian legislative acts to promote the EU directive of the European Parliament and of the Council of 21 October 2009, establishing a framework for community action to achieve the sustainable use of pesticides.

## ACKNOWLEDGEMENTS

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