Cost-Benefit Analysis of Sterile Insect Technique for Oriental Fruit Fly, *Bactrocera dorsalis* (Hendel), Management

Bactrocera dorsalis (Hendel), photograph by Scott Bauer, USDA.

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Executive Summary

In this study we conducted a cost-benefit analysis of sterile insect technology (SIT) as a management tool for oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) (OFF). The analysis was done at the request of the Fruit Fly Exclusion and Detection Cross Functional Working Group. SIT has been successfully used by the Mexican fruit fly (Mexfly), *Anastrepha ludens*, and Mediterranean fruit fly (Medfly), *Ceratitis capitata*, management programs in the United States. The Working Group wanted to know if this tool could also be economically viable for the management of OFF.

We estimated the costs of an SIT for OFF and compared them to its expected benefits in reducing OFF eradication costs. We assumed that OFF SIT would be applied in a similar way as preventive release program for Medfly in California and estimated that such a program for OFF would cost approximately $16 million annually. In comparison, past eradications of OFF cost the Federal government and the state of California only $649,000 annually on average. Residents, farmers markets, and commercial fruit growers experienced some additional losses during OFF eradications, but these losses were relatively small.

Because the estimated OFF SIT program costs significantly outweigh the expected program benefits in reducing eradication costs, it is unlikely that OFF SIT could be economically viable at the current level of OFF incursions. Current OFF eradications have relatively low costs because of the availability of highly effective male attractant methyl eugenol, which allows to detect and eradicate OFF quickly. Further, imminent changes to the OFF situation in California are unlikely, implying that the OFF SIT would not become economically viable in the near future.

1. Introduction

The oriental fruit fly (OFF), *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), is a polyphagous pest endemic to Southeast Asia (Clarke et al., 2005; Manoukis et al., 2018). The species is highly invasive and now occurs throughout tropical Asia and Africa, as well as the Pacific Islands, including Taiwan and Hawaii (CABI, 2021; Manoukis et al., 2018). OFF is periodically detected and eradicated in California and Florida and is considered a serious threat to agriculture in the United States (Alvarez et al., 2016; Barr et al., 2014).

Sterile insect technique (SIT) is a pest management method that relies on the release of an overwhelming number of sterile insects into the wild. Wild females mate with sterile males producing no offspring, which reduces pest populations (Dyck et al., 2021). SIT has been an important component of the Mexican fruit fly (Mexfly), *Anastrepha ludens,* (McCombs et al., 2009) and Mediterranean fruit fly (Medfly), *Ceratitis capitata*, (CDFA, 2021b; PPQ, 2003) management programs in the United States. Management of OFF in the United States does not employ SIT, but relies on the male attractant methyl eugenol (ME), both for detection trapping and - in combination with an insecticide - for the male annihilation technique (Manoukis et al., 2019; PPQ, 1989).

The Fruit Fly Exclusion and Detection Cross Functional Working Group asked Plant Pest Risk Analysis unit to evaluate if an SIT could be economically viable for the management of OFF. We applied the cost-benefit analysis to conduct this evaluation.

2. Analytical Approach

An SIT for OFF is only a remote possibility. Current SIT programs for fruit fly management in California, Florida, and Texas differ in terms of sterile fly rearing, release protocols, and funding. Because we did not know the details of how SIT would be applied against OFF, our cost-benefit analysis relied on the following assumptions:

- *OFF SIT would be applied in California*. OFF eradications are more frequent in California compared to other locations; there were 12 OFF eradications in California and only one in Florida since 2009 (PPQ, 2020).[1]

- *Sterile OFF insects would be released at constant levels year-round*. SIT can also be used to help eradicate fruit flies. Thus, sterile insects are typically produced and released at certain levels for prevention year-round with production and release quantities ramped up during eradications. However, future OFF eradications are difficult to predict, especially under preventive SIT.

- *OFF larvae would be reared and sterilized at the Fruit Fly Rearing Facility (FFRF) in Waimanalo on Oahu, HI, and shipped to California to complete the rearing process at the Sterile Fruit Fly Emergence and Release Facility (ERF) in Los Alamitos, CA.* To prevent new pest introductions, the rearing and sterilization of OFF has to occur where

[1] Florida may benefit from California having an SIT for OFF by obtaining sterile insects for eradications. However, the associated impacts are beyond the scope of this analysis.

the pest is either already established or where it cannot establish because of unsuitable climate (Manoukis, 2020). Rearing OFF in areas within the conterminous United States where this pest cannot establish because of low temperatures in winter months is a possibility, but strong resistance from local agricultural industry is likely (Manoukis, 2020).[2]

- *Release rates, frequency, and areas for preventive OFF SIT in California will be the same as they currently are for Medfly*. Medfly and OFF eradications have occurred in similar areas in California; therefore, the same areas are likely to be prioritized for OFF sterile insect release (Leathers, 2021; Walters, 2021).

3. Estimation of the OFF SIT costs

We obtained the costs of preventive Medfly SIT from CDFA program staff and used them to estimate the costs for OFF SIT. To do this, we identified various reasons why the costs might differ between OFF and Medfly based on interviews with subject matter experts and available literature. For example, the Medfly program uses the temperature sensitive lethal genetic sexing strain, which eliminates female flies early in the rearing process to reduce costs (Meza et al., 2018; Rendon, 2021; So, 2021). This strain is not yet available for OFF (Manoukis, 2020; Rendon, 2021). Instead, we assumed the OFF program would use the currently available pupal color-based genetic sexing strain (McCombs and Saul, 1995). For this strain, both male and female larvae are reared until they can be separated based on color (McCombs and Saul, 1995; Shelly, 2020). Thus, rearing would cost more for OFF.

In estimating OFF SIT costs, we focused on operational costs of rearing, eclosion, and release and assumed that the required infrastructure and equipment were available. We also based our analysis on current costs and did not account for future inflation.

Costs to rear sterile OFF larvae in Hawaii

We obtained rearing costs for sterile Medfly from the Hawaiian FFRF. The rearing costs were broken down into three major categories: larval diet, labor, and rent and utilities. Approximately 180 million sterile Medfly larvae must be produced weekly to support the preventive release program in California (Walters, 2021). Currently, the Hawaiian FFRF is only producing around 112 million sterile Medfly per week due to a reduced capacity of cooling equipment (So, 2021). The Hawaiian FFRF expects to reach the needed production level in the near future (So, 2021). We asked program staff how rearing costs would be affected when this happens. These costs are explained below and summarized in Table 2 including our cost estimates for OFF production at 180 million per week.

Larval diet

The estimated annual cost of the larval diet required for the weekly production of 180 million sterile male Medflies is $1.3 million (So, 2021). Diet composition for OFF is similar to the diet of Medfly (Rendon, 2021). However, OFF larvae are larger than Medfly larvae, so 30 percent

[2] OFF is also now found year-round in more temperate areas in China (Manoukis, 2021), which further reduces potential areas where rearing of OFF could occur within the conterminous United States.

more diet would be required for the same quantity of OFF (Geib, 2020; Manoukis, 2020; Rendon, 2021). In addition to this, even more diet would be required because a temperature sensitive lethal strain is not available for OFF. Females would need to be reared and fed, and because color-based sorting identifies only 40 percent of the flies as male (60 percent are discarded) (Geib, 2020; Manoukis, 2020; Rendon, 2021), there would be an additional 150 percent increase in diet. Overall, we estimated that the costs of diet would more than triple for OFF as compared to Medfly and be around $4.225 million per year.

Labor

An estimated 25 personnel are needed to support the weekly production of 180 million sterile male Medflies, at an annual cost of $1.63 million (So, 2021). For OFF, we assumed that 40 personnel would be sufficient to handle the larger quantity of diet and larger number of rearing trays, and to operate sorting equipment. Estimated cost was $2.608 million per year.

Rent and utilities

The current long-term rental agreement for the facility that is used to rear Medfly in Hawaii has an annual cost of $150,000, and the facility is paying approximately $400,000 per year in utilities (So, 2021). We assumed that these costs would be the same for OFF.

Costs of shipping to the eclosion facility in California

Medfly pupae are shipped several times per week to California's eclosion facility using a commercial airline. FFRF staff deliver Medfly pupae to the airport, and the airline charges $125 per 2 million pupae for delivery to California (So, 2021). The annual Medfly shipping costs would be $585,000 based on 180 million sterile flies per week. Shipping costs would be higher for OFF because the pupae are larger. We estimated these costs to be $760,500 per year based on 30 percent increase in the volume/weight of shipment for the same quantity of pupae.

Costs of the eclosion facility in California

The ERF facility in California supports several of the state's fruit fly program activities (e.g., program management, identification, eclosion, and release of various fruit flies) that vary from year to year, and identification of costs specific to the sterile Medfly eclosion stage presented a challenge. Thus, we estimated these costs by finding the difference between the total Medfly preventive SIT program costs, approximately $12 million per year (Walters, 2021), and the other cost components we were able to identify: rearing at FFRF ($3,480,000), shipping ($585,000), and release ($3,400,000). We estimated the Medfly eclosion costs at $4,535,000. The eclosion process is likely to be similar for OFF (Walters, 2021), and we assumed that the associated costs would be the same.

Costs of release

Preventive release of sterile Medfly in California is conducted by contracted airplanes and pilots costing $750 per flight hour for the equipment and the time of two pilots[3] and $150-$200 per flight hour in fuel costs. With 3,600 contracted release flight hours per year (Wright, 2021), we

[3] The release contract includes the maintenance of release equipment. Two pilots are needed because of relatively challenging flying conditions in the heavily trafficked release area. One of the pilots operates the release equipment (Walters, 2021).

estimated annual Medfly preventive release costs at $3.4 million. Because it is likely that the SIT program for OFF in California would have a similar release area, fly quantities, and methods as the preventative SIT program for Medfly (Leathers, 2021; Walters, 2021), we assumed that the release costs would be the same. Some savings in release costs would be possible if both sterile Medfly and OFF were released simultaneously, which is technically feasible (Walters, 2021). However, for such savings to become possible, future release areas and protocols must match for Medfly and OFF. We could not assess how likely that would be and we did not consider the associated savings in this analysis.

Summary of all costs for OFF SIT

Table 1 summarizes our cost estimates for the preventive SIT program for Medfly and OFF in California. The program for Medfly costs an estimated $12 million per year, and the program for OFF was projected to cost approximately $16 million per year. This cost difference was primarily due to the greater quantity of diet required to rear OFF larvae. OFF larvae are larger than Medfly, and, unlike with Medfly, OFF female larvae need to be reared up to the time when they can be separated based on color.

Table 1. Summary of estimated annual costs of preventive SIT programs for Medfly and OFF in California

Cost category	Medfly at 180 million per week, $	OFF at 180 million per week, $	Assumptions to estimate OFF costs (as compared to Medfly)
Rearing in HI	3,480,000	7,383,000	
Diet	*1,300,000*	*4,225,000*	30 percent more due to larger size; 150 percent more due to need to rear females which are discarded based on color after sorting[a]
Labor	*1,630,000*	*2,608,000*	25 positions for Medfly, 40 positions for OFF
Rent	*150,000*	*150,000*	No change
Utilities	*400,000*	*400,000*	No change
Shipping to CA	585,000	760,500	30 percent more because of larger size
Eclosion in CA	4,535,000	4,535,000	No change
Release in CA	3,400,000	3,400,000	No change
Total annual costs	12,000,000	16,078,500	

[a] Because of color variation, only about 40 percent of pupae can be identified as male during sorting (Geib, 2020).

4. Estimation of the OFF SIT benefits

The benefit of a successful SIT program for OFF would be in eliminating the need for repeated eradication efforts. The costs of such efforts are detailed below.

Federal and state costs of OFF eradication

OFF eradications may include delimitation surveys, host fruit surveys, soil treatments, bait sprays, male annihilation treatments, and establishment of a quarantine area with restricted movement and inspections of regulated articles (CDFA, 2021a; PPQ, 1989). The selected response tools vary depending on the circumstances, making it difficult to accurately estimate the associated costs. In addition, detailed cost information is not well tracked as costs and response actions are spread over the Federal, state, and county governments. As our primary information source we used a PPQ summary document (PPQ, 2020) of key information on all past fruit fly responses up to 2018, including descriptions of response actions and associated costs. Table 2 summarizes key information from this report.

Table 2. Key information on OFF and Medfly eradications in California from 2009 to 2018

	Medfly	OFF
Total eradications	13	12
Average number of eradications per year	1.3	1.2
Average duration of eradication [days][a]	265	240
Average costs per year[b,c]	$1,469,000	$649,000
Average costs per eradication[c]	$1,130,000	$541,000

[a] Estimated from the date of the first detection to deregulation.

[b] Source (PPQ, 2020). We were not able to verify all eradication costs reported in this document. For some, the original reference document (e.g., Medfly emergency response budgets provided by California) was available for review (Marnell, 2021) and included both the Federal and state costs. However, it is possible that for some other eradications, only the Federal costs were reported. State costs vary, but are around 50 percent of the total eradication costs on average (Wright, 2021), and if not currently included, would make the true costs higher than our estimates. This discrepancy, however, would not affect the conclusion of this report.

[c] Presented values are adjusted for inflation and represent a dollar value in 2021 (BLS, 2021).

Other costs of OFF eradications

Private entities may incur some costs due to OFF eradications, which typically occur in residential areas (Leathers, 2021). Though any response actions, such as fruit stripping, carried out in residential areas are typically done and paid for by the program (Leathers, 2021; Wright, 2021), households within a 100-meter radius from an OFF detection may lose host fruit grown on their property (CDFA, 2021a). In addition, sellers in farmers markets within a 4.5-mile radius of an OFF detection are required to cover host fruit with protective netting, and some host fruit may be confiscated (Leathers, 2021). Any associated losses are likely small (Leathers, 2021).

California is a major producer and exporter of OFF host fruit (FAS, 2021; NASS, 2021). Currently, commercial growers in regulated areas may continue selling host fruit if they apply treatment 30 days prior to harvest (Alvarez et al., 2016; Leathers, 2021). The treatment costs an estimated $97.46 per acre[4] (Alvarez et al., 2016). However, commercial producers rarely have to apply preharvest treatment or lose harvests because OFF eradications rarely occur in the commercial production areas (Leathers, 2021).

5. Conclusion and discussion

For the OFF SIT to be economically viable, its expected benefits need to outweigh its costs. The primary benefit of SIT for OFF would be the elimination of eradication costs to the Federal government and the state of California of approximately $649,000 per year. This estimate assumes 100 percent effectiveness of the SIT method; otherwise, the benefits would be lower. On the other hand, the costs of an OFF SIT would be approximately $16 million annually.

[4] $88.60 per acre in 2016 (Alvarez et al., 2016) adjusted for inflation (BLS, 2021).

Therefore, we do not believe that OFF SIT can be economically justified at the current incursion level.

Because we did not know in detail how SIT would be applied against OFF, we had to rely on several assumptions to conduct this analysis. To estimate the costs of OFF SIT, we made assumptions about required release quantities and resources needed to rear and release sterile flies. In addition, we faced limitations in obtaining accurate OFF eradication costs which we used to estimate the benefits of OFF SIT. However, the conclusions of our cost-benefit analysis should not be affected by these limitations and our assumptions because the expected costs of OFF SIT significantly outweigh eradication costs.

The primary reason for relatively low eradication costs, $649,000 per year for OFF compared to $1,469,000 for Medfly (Table 2), is the availability of ME, which is inexpensive, but highly effective attractant (Leathers, 2021). With ME, OFF can be located and eradicated quickly and at lower costs compared to Medfly which requires more expensive SIT to eradicate.

OFF eradications in California have been infrequent, with an average of 1.2 per year in the past ten years. Though the frequency of new fruit fly incursions can vary over time depending on human activity (Leathers, 2021), the subject matter experts we consulted did not foresee any imminent change to the current OFF situation in California (Leathers, 2021; Manoukis, 2021). Further, program staff indicated that each year they could successfully manage three to four times higher levels of OFF eradication efforts with their current resources (Leathers, 2021).

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