Sterility in Trouble: When Pest Mating Challenges Sterile Insect Technique Success

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The sterile insect technique (SIT) is increasingly used in agriculture to manage crop pests. It involves the large-scale breeding, sterilization, and release of targeted insects into crops. This approach reduces population reproductive output and the resulting crop damage. However, despite its theoretical simplicity, each step of SIT poses practical challenges that may hinder its success. Several challenges, such as residual fertility in sterile insect releases and female re-mating behavior, can significantly impede SIT success.

To assess the impact of (1) residual fertility and (2) multiple mating on SIT efficiency, we develop a population dynamics model based on ordinary differential equations. The model includes five compartments : larvae, wild males, sterile males, fertilized females (mated with wild males), and infertile females (mated with sterile males). Sterile males are released continuously. Only fertilized females are able to lay eggs, and fertility is determined by the last mating—allowing females to change status if and when they re-mate.

(1) We determine the residual fertility threshold below which eradication can be achieved. This threshold depends on the offspring number of the targeted pest and fitness costs on released males. Moreover, pest control remains feasible even when this threshold is overshot. In this case, SIT allows the pest population to be maintained under an acceptable level.

(2) We compare scenarios where females undergo single mating with multiple matings separated by a refractory period. We investigate the impact of this refractory period, which can vary depending on whether it follows a mating with a fertile or sterile male.

To further explore the consequences of multiple mating, we investigate biases in sperm use by developing an agent-based model calibrated on *Drosophila suzukii*. This framework allows us to simulate and compare various scenarios : preferential use of the first sperm, preferential use of the last sperm, mixed utilization of stored sperm, and female preference for fertile or sterile sperm.

Our results highlight how residual fertility, multiple mating and sperm use bias modulate SIT effectiveness. Although multiple mating is generally disadvantageous for SIT - requiring higher release ratios - it may, in some cases, accelerate short-term population decline. Moreover, post-mating mechanisms have a limited impact on SIT performance when sufficient release effort is ensured.

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