# COLD TORPOR AND FLIGHT THRESHOLD OF *ANASTREPHA SUSPENSA* (DIPTERA: TEPHRITIDAE)

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ABSTRACT

The Caribbean fruit fly, *Anastrepha suspensa* (Loew), is a pest of quarantine significance of many subtropical fruits in Florida. Fly free zones which require bait spraying with malathion when fly populations reach actionable levels, have been developed. Bait sprays also are used whenever new introductions of fruit fly species occur. Bait sprays will not be effective if the target population is immobile due to cold.

The purpose of this study was to develop temperature thresholds for laboratory-reared and wild *Anastrepha suspensa* through controlled laboratory studies. This research determined that the cold torpor threshold for Caribbean fruit fly was 11.4°C, and the flight threshold for 50% of the population was about 20°C. It also was determined that the flight threshold of wild flies did not differ significantly from that of laboratory reared flies.

Bait spray experiments and regular treatments could be scheduled to avoid cold periods when flies are not active.

Key Words: Caribbean fruit fly, *Anastrepha suspensa*, cold torpor threshold, flight threshold

RESUMEN

La mosca de la fruta del Caribe, *Anastrepha suspensa* (Loew), es una plaga de muchas frutas subtropicales en la Florida y es de importancia cuarentenaria. Zonas libres de estas moscas, cuales requieren rocío de carnada con malathion cuando la población de moscas llega a niveles punibles, han sido desarrolladas. Rocíos con carnada también son usados cuando ocurren introducciones de otras especies de moscas de frutas. Este tipo de rocío no es efectivo si la población de moscas ha sido inmovilizada por el frío.

El propósito de este estudio fué el desarrollar umbrales de temperaturas para *Anastrepha suspensa* a través de estudios controlados en el laboratorio y confirmación de los resultados con moscas silvestres. Este estudio específicamente determinó que el umbral de inactividad de las moscas de la fruta del Caribe causado por frío fué de 11.4°C, y que el umbral de vuelo para el 50% de la población fué de 20°C. También fué determinado que el umbral de vuelo de moscas silvestres no varió significativamente del obtenido con las moscas criadas en el laboratorio.

Experimentos con rocíos de carnada y tratamientos regulares pueden ser programados para evitar períodos de frío cuando las moscas están inactivas.

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The Caribbean fruit fly, *Anastrepha suspensa* (Loew), developed into a quarantine problem for the Florida citrus industry after the fly became established in the mid 1960s. Fly free zones have been developed as a major defense for Florida citrus exports (Greany and Riherd 1993, Riherd 1993, Riherd et al. 1994). Current protocols for the fly free zones require bait spraying with malathion whenever trapping detects fruit fly populations of 2 or more adults within 2.4 km of each other in the zone during a 30 day period (Riherd et al. 1994). Once fly populations reach actionable levels, bait sprays of Nulure® (Miller Chemical and Fertilizer Corp., Hanover PA) and malathion are used to reduce populations. Bait sprays also are a main line of defense in the eradication of new introductions of fruit flies such as the recent Mediterranean fruit fly outbreak in the Tampa, FL area (Nguyen et al. 1992, Glickman 1997).

The effectiveness of a bait spray depends on the flies being able to come into contact with and/or consume the bait in sufficient quantity to kill the fly. The following physiological parameters are important: the temperature in the field at which the flies are active (torpor threshold), the temperature at which they can fly, and the temperature at which the flies begin normal activities such as feeding, mating and oviposition. With this information bait spray experiments and regular treatments can then be scheduled to avoid periods when flies are not active.

*Dacus tryoni* (Froggatt) is one of the few fruit fly pests for which many of these temperature thresholds have been determined (Meats 1989). For most other fruit fly species this information is not available. The purpose of this study was to develop temperature thresholds for *A. suspensa* through controlled laboratory studies with colony reared insects and then confirm these results with wild flies. Specifically, this research determined a cold torpor threshold and a flight threshold for *A. suspensa*. Studies are in progress to determine an oviposition threshold and a feeding threshold.

## MATERIALS AND METHODS

Cold torpor threshold: The adult flies used in this experiment were from a colony reared on artificial media in the laboratory in Miami, FL, and were 5 to 7 days old. Five flies were placed in a 100 × 15 mm plastic petri dish. Paper with a 2 cm grid was placed on one side of the petri dish to allow fly movement to be measured. The petri dish was held vertically by a small c-clamp. A small hole (2 mm in diameter) in one edge of the petri dish had a j-type thermocouple installed. A tele-thermometer used to measure the temperature was calibrated with a National Standards Traceable mercury thermometer. The petri dish with flies and thermocouple was placed in an incubator with the temperature initially at about 25-26°C. The incubator was equipped with fluorescent lights that were positioned directly over the petri dish at a distance of 10 cm. The flies were allowed to acclimate for 10-20 minutes. After the acclimation period, the temperature was lowered at a rate of 2-3°C per 10 minutes for the first hour and 1°C per min after that, until 5-7°C was reached. A Sony® CCD F-70 8mm video recorder was used to record fly activity during the tests. The recorder was placed 40 cm from the petri dish containing flies and activity was recorded at 2× magnification. The video was played back on a television monitor and at 10 minute intervals the total distance moved by each fly in the petri dish was measured for a one minute period by using the 2-cm grid present in the petri dish. Temperature was recorded at the beginning of each interval. This experiment was repeated 6 times with flies from different rearing batches for both males and females.

Flight threshold: Adult flies used were from the colony mentioned above, and were 5 to 7 days old. The flies were cooled at 1°C for several minutes until they were torpid. Ten male and 10 female flies were placed into two 400-ml glass beakers. The upper portion of the inside of each beaker was coated with talc which the flies could not climb. The beakers with flies were placed in a small cage (30 × 30 × 30 cm) in an incubator at a fixed temperature (12, 14, 16, 18, 20, 22, 24, or 26°C). After 1 hour the number of flies that flew out of the glass beaker was recorded. This experiment was repeated 10 times with different groups of flies. The incubator was equipped with fluorescent lighting which was located 10 cm directly above the cage containing flies. Wild flies were tested against colony flies to determine if they differed significantly in flight ability. Guavas were purchased from a packing house in Homestead, FL (24 km from the USDA facility). Larvae recovered from guavas were held under identical conditions as colony flies until adults emerged. The adult flies were tested when 5 to 7 days old in side by side tests identical to those previously described in the same incubator at 20°C. This temperature was chosen as an intermediate temperature at which only a portion of the flies would fly. Eight replications of 10 colony males and 10 colony females were tested at the same time as 10 wild males and 10 wild females.

Statistics: Statistical analysis was performed using linear regression (proc reg) and t-test (proc ttest) (SAS Institute 1988) and also by fitting non-linear transition models using TableCurve 2D® (Jandel Scientific 1994).

## RESULTS AND DISCUSSION

Cold Torpor Threshold: Fly movement decreases as the temperature is decreased (Fig. 1). There was no significant difference between males and females. The data distribution shows higher variation in fly movement at the warmer temperatures. At the warmest temperatures, some flies moved large distances but others flies did not move. This variation could influence the slope of a regression and predictions of the temperature threshold for movement. Therefore a number of transformations were performed on the data. The transformation that gave the best 'fit' to a linear regression was log 10 of distance traveled (Fig. 2). The transformed regression gives a cold torpor threshold (X intercept) of *A. suspensa* of 11.4°C vs 13.5°C for the non-transformed regression.

The torpor thresholds for *Dacus oleae* (Gmelin) (2.7°C) and *D. tryoni* (2°C warm acclimated and 7°C cold acclimated) are much lower (Meats 1989). However both of these flies have ranges that regularly include colder temperatures. The original range of *A. suspensa* encompassed only sub-tropical climates where the temperatures seldom dropped this low.

Flight threshold: As with cold torpor threshold of movement, flight increases with increasing temperatures. The relationship is a sigmoid curve (Fig. 3). The male and fe-

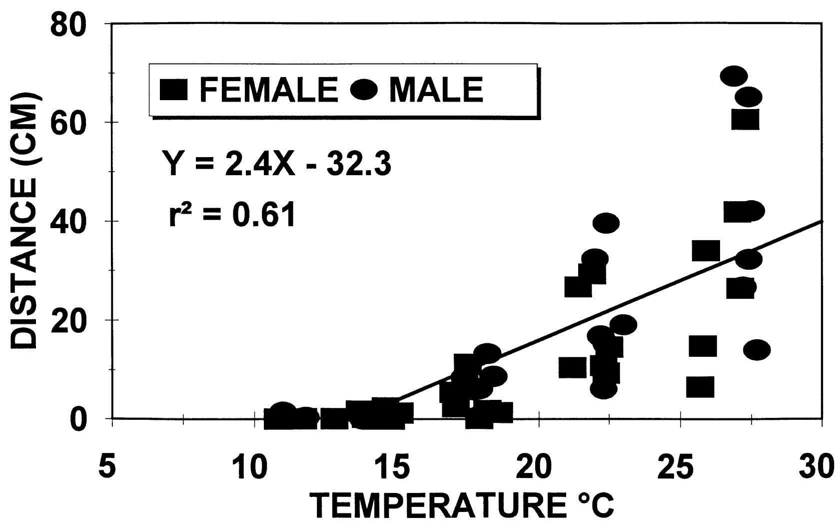


FIG. 1. Distance (cm) moved by male (circles) and female (squares) Caribbean fruit fly adults versus temperature.

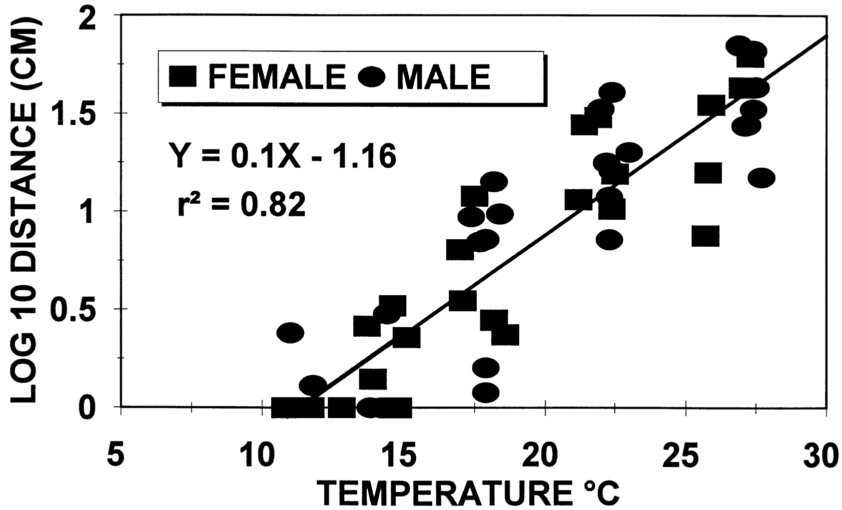


FIG. 2. $Log_{10}$ of Distance (cm) moved by male (circles) and female (squares) Caribbean fruit fly adults versus temperature.

male flies have similar curves except at temperatures of 22 and 24°C where the confidence limits indicate that the two are significantly different. The flight threshold value differed widely among individual flies, a few flies can fly at 18°C, but most won't. The 50% flight threshold, which is the point of inflexion of the sigmoid curve (about 20°C), is probably a better figure for determining when to conduct bait spray tests. Us-

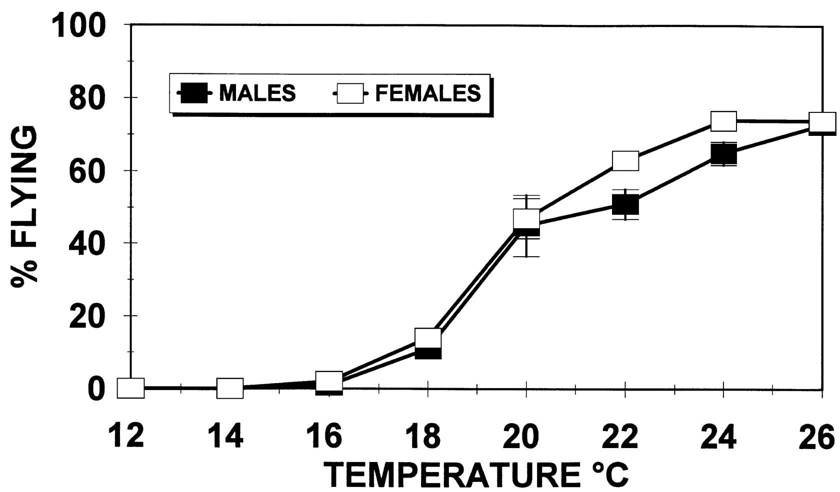


FIG. 3. Percent of male (filled boxes) and female (open boxes) Caribbean fruit fly adults flying versus temperature.

ing Tablecurve 2D® to fit to the data set for female flies, several sigmoid transition curves fitted with $r^2 > 0.99$. The 50% flight threshold (the percentage based on the total number of flies which flew at the warmest temperature) was about 19.5°C for the best fitting equations. At 22 and 24°C some male flies remained in the beaker and appeared to display mating behavior (Burk 1983, Sivinski et al. 1984, Sivinski 1989). Again, as with the cold torpor, some of the flies remain motionless regardless of temperature.

To determine if the thresholds were the same for colony reared vs wild flies, we reared and compared the two side by side. The proportion of flies flying at 20°C was $0.53 \pm 0.23$ for colony flies and $0.45 \pm 0.24$ for wild flies. This difference was not significant ($t = 0.98$, 30 DF, $P = 0.34$). Therefore the colony flies differ little if any from the wild flies in their propensity to fly at the temperature tested.

The flight temperature thresholds for *Dacus dorsalis*, *D. oleae*, and *D. tryoni* are all 14°C (Meats 1989) which is several degrees colder that the flight threshold of 16-18°C, and 20°C 50% flight threshold for *A. suspensa*. Again, these differences might be due to *A. suspensa* adaptations to its restricted subtropical range.

Any large scale tests or control programs with baits for *A. suspensa* should be planned to avoid cold periods when the majority of the daytime temperatures in Florida fall below the temperature thresholds. In north and central Florida, winter maximum temperatures often fall below the flight threshold of the Caribbean fruit fly and minimum temperatures fall below the torpor threshold (National Climatic Data Center 1991).

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