FEMALE *ANASTREPHA SUSPENSA* (LOEW) RESPONSE TO THE VIBRATION COMPONENT OF MALE WING-FANNING SIGNALS

Mackenzie Egan & Richard Mankin

USDA-ARS Center for Medical, Agricultural, and Veterinary Entomology, 1700 SW 23rd Dr, Gainesville, Florida USA 32608

Abstract *Anastrepha suspensa* (Loew) is an important pest of fruit crops in Florida and islands in the Caribbean region. Courtship and mating behaviors have been analyzed in previous studies to develop control methods. During courtship, males group in leks on leaves of host trees, fan their wings, and release pheromone to attract females. The wing fanning vibrations are transferred though their legs to the leaves and nearby stems. We hypothesized that females detect these wing-fanning vibrations, and their behavioral responses may affect the likelihood of mating. Bioassays were conducted in which females were exposed to periods of male wing-fanning vibrations and periods of quiet. The females flew or moved about less often during vibration periods than during quiet periods. This suggests that wing-fanning vibrations may function partly to reduce the likelihood that a female will move away from a male who approaches her to mate.

Keywords Tephritidae, Caribbean fruit fly, courtship

Introduction

Economic losses caused by the Caribbean fruit fly, *Anastrepha suspensa* (Loew), to fruit crops in central and southern Florida and the West Indies have prompted considerable research to develop improved methods of managing these and other important Tephritid pests. Part of the research has focused on development of methods to interfere with mating. In previous studies, it was observed that males gather in leks on a host plant where they defend space on the underside of a leaf (Burk 1983). There, they release a pheromone and produce wing-fanning buzzes, attracting females to the leaf (Webb et al. 1984). Once on the leaf, she can choose to mate with one of the males or to fly away (Webb et al. 1984).

The mechanics of wing-fanning movements necessarily transmit vibrations from the fly thorax to its legs, then to the leaf and the nearby stems and branches. Until now, it has never been determined whether such vibrations are detected by females or whether the vibrations affect their behavior. However, other insect species, including the phytophagous stink bugs (Pentatomidae), are known to transmit vibrational signals through substrates to facilitate orientation towards mates (Čokl 2008). Male *Okanagana rimosa* (Say) cicadas have been reported to produce vibrations concomitant with acoustic calls (Stölting et al. 2002). The vibrations likely are involved in mate location once the female lands near the male. Vibrations produced by male water striders, *Gerris gracilicornis* (Horvath) play a role in inducing females to accept male courtship (Han & Jablonski 2009). If *A. suspensa* females use substrate vibrations to locate males or if the vibrations influence mating receptivity, it may be possible to devise improved methods of controlling these pests by interfering with mating.

For this report, we measured substrate vibrations produced during wing-fanning by male *A. suspensa* and conducted bioassays to determine whether (virgin) females respond to the vibrational component of wing-fanning. To consider whether previous exposure to male pheromone affected a response to vibrational signals, separate groups of females were tested. One group was kept separate from any contact with males, while the second group was exposed to a cage of calling males on the day before the bioassay.

Materials and Methods

Irradiated *A. suspensa* pupae were obtained from a sterile-release rearing facility at the Division of Plant Industry, Florida Department of Agriculture, Gainesville, FL. The flies were sexed and separated into 30- by 30- by 30-cm plastic screen cages within 48 h after emergence. Thereafter, males and females were kept in separate rearing rooms. Acoustic and vibrational signals were recorded in a vibration-insulated anechoic chamber (Mankin et al. 2000a) at the USDA-ARS Center for Medical, Agricultural, and Veterinary Entomology, Gainesville, FL.

Wing-fanning vibrations of 5-7-day-old males calling from leaves of a strawberry guava host plant, *Psidium cattleianum*, were recorded with two accelerometers (Brüel and Kjær [B&K], Type 4370) attached to adjacent stems and branches. A microphone (B&K model 4145) was used to record the wing fanning sounds simultaneously. The signals were band-pass filtered between 100 and 1500 Hz, and were analyzed by methods described in Mankin et al. (2000a; 2004). A 2-min file was created from a representative, 11-s period of male wing-fanning, with 1 min of continuous repetition of the 11-s wing-fanning, followed by 1 min of silence without signals. The file was played back in an endless loop by a vibration exciter (B&K model 481) attached to the base of a 8-cm-diam. by 8-cm-long screen mesh cylindrical cage containing 10 females, 8-10-d old. The vibration level was not sufficiently high in the playbacks to produce sounds that could be detected with a microphone, but the vibrational signals detected by an accelerometer attached to the cage were approximately the same amplitude as those detected by an accelerometer attached to a stem near a wing-fanning male. The tests were conducted during 4-h periods beginning 8.5 h after the start of the photoperiod (Mankin et al. 2000b). The virgin females either were kept totally separate from males (13 tests) or their cage was placed on a table near a cage of males 20 h before tests (12 tests).

The behaviors of the females were observed remotely using a video camera during 10 consecutive playbacks of the 2-min vibration on/off cycle. Movement was defined as activities typical of avoidance or disturbance behavior, including spinning around, walking, wing-fanning, and flying. The numbers of moving females were scored at the midpoint of each 1-min wing-fanning or silence period. If the female was resting or grooming at the wing-fanning or silence midpoint, she was scored as quiet. The total numbers moving or quiet at each midpoint were summed to score each 20-min test.

Results and Discussion

Sixteen periods of *A. suspensa* male calling from five different males were recorded in which signals were detected from one or both accelerometers and the microphone. A representative example containing four consecutive bursts of wing fanning is shown in Fig. 1.

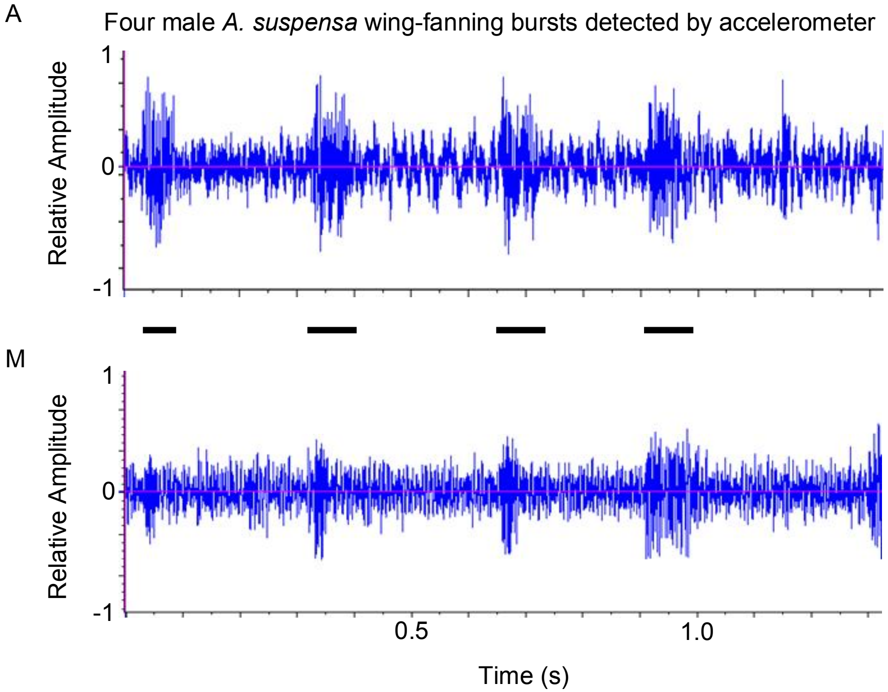

Figure 1. Comparison of wing-fanning bursts recorded from a male *A. suspensa* detected simultaneously by an accelerometer (A) and a microphone (M). Solid bars denote the intervals of wing-fanning.

The slight differences in the timing and relative amplitudes of the accelerometer and microphone signals can be attributed to differences in the distances between the fly and the sensors as well as to multiple reflections from boundaries or to resonances or other substrate-induced distortions in the signal detected by the accelerometer. An accelerometer recording of a longer, 11-s period of wing-fanning by a male *A. suspensa* was concatenated to complete a 1-min period of wing-fanning vibrations for playback to females.

In the 20-min tests with 1-min periods of vibration followed by 1-min periods of silence, fewer females were active at the midpoints of wing-vibration periods than at the midpoints of silent periods. For females who had never been exposed to male pheromone, a mean of 12.7 ± 1.6 females per test were moving at the midpoint of the vibration period compared to 16.8 ± 2.2 moving at the midpoint of the silent period (t = -2.44, df = 12, P = 0.03), i.e., 0.13 movements/fly/min of broadcast compared to 0.17 movements/fly/min of silence. When females were pre-exposed to males on the day before testing, a mean of 14.4 ± 1.4 were moving at the midpoint of the vibration period compared to 19.25 ± 1.9 at the midpoint of the silent period (t = -2.84, df = 11, P = 0.02) or 0.14 movements/fly/min of broadcast compared to 0.19 movements/fly/min of silence.

The differences in movement in the wing-fanning and quiet periods suggest that female *A. suspensa* can detect the male wing-fanning vibrations, just as they detect the wing-fanning sounds, and the vibrations may reduce the likelihood that the female will move away from the male who approaches her to mate. The observed effects of vibrations on *A. suspensa* females are similar in many respects to the effects of wing-fanning sounds on female *Ceratitis capitata* (Wiedemann) females (Liimatainen et al. 1997; Briceño & Eberhard 2002), and the two signals may have synergistic effects.

The results of this study lead immediately to other questions of both basic and practical interest. Preliminary bioassays with background noise and wing buzzes of non-tephritid species were negative, indicating that this effect is not simply a generalized response to vibration. But it remains unknown whether female *A. suspensa* or other tephritids are affected by vibrational signals of related species, or whether wing-fanning vibrations and sounds combine synergistically to affect mating behavior. There also is a possibility that the effects of substrate vibrations on *A. suspensa* females could be affected by differences in the type of substrate on which mating occurs (see Joyce et al. 2008). Finally, it is not known whether this newly observed effect of wing-fanning vibrations can be exploited for development of improved methods of managing *A. suspensa* or other tephritids.

Acknowledgments

We thank Everett Foreman, Betty Weaver, Chloe Hale, and Emilie

Bess for assistance in setting up, observing, and analyzing bioassays.

References

Briceño, R.D., & Eberhard, W.G. Decisions made during courtship by male and female medflies (Diptera: Tephritidae): correlated changes in male behavior and female acceptance criteria in mass-reared medflies. Florida Entomol. 85: 14-31.

Burk, T. 1983. Behavioral ecology of mating in the Caribbean fruit fly *Anastrepha suspensa* (Loew) (Diptera: Tephritidae). Florida Entomol. 76: 678-682.

Čokl, A. 2008. Stink bug interaction with host plants during communication. J. Insect Physiol. 54: 1113-1124.

Han, C.S., & Jablonski, P.G. 2009. Female genitalia concealment promotes intimate male courtship in a water strider. PLoS ONE 4: e5793.

Joyce, A.L., Hunt, R.E., Bernal, J.S., Vinson, S.B. 2008. Substrate influences mating success and transmission of courtship vibrations for the parasitoid *Cotesia marginiventris*. Entomol. Exp. Et. Appl. 127: 39-47.

Liimatainen, Hoikkala, J. A., Shelly, T. 1997. Courtship behavior in *Ceratitis capitata* (Diptera: Tephritidae) Ann. Ent. Soc. Am. 98: 836-843.

Mankin, R.W., Anderson, J.B., Mizrach, A., Epsky, N.D., Shuman, D., Heath, R.R., Mazor, M., Hetzroni, A., Grinshpun, J., Taylor, P.W., Garrett, S.L. 2004. Broadcasts of wing-fanning vibrations recorded from calling male *Ceratitis capitata* (Diptera: Tephritidae) increase captures of females in traps. J. Econ. Entomol. 97: 1299-1309.

Mankin, R.W., Brandhorst-Hubbard, J., Flanders, K.L., Zhang, M., Crocker, R.L., Lapointe, S.L., McCoy, C. W., Fisher, J.R., Weaver, D.K. 2000a. J. Econ. Entomol. 93: 1173-1182.

Mankin, R.W., Petersson, E., Epsky, N.D., Heath, R.R., Sivinski, J. 2000b. Exposure to male pheromones enhances *Anastrepha suspensa* (Diptera: Tephritidae) female response to male calling song. Florida Entomol. 83: 411-421.

Stölting, H. Moore, T.E., Lakes-Harlan, R. 2009. Substrate vibrations during acoustic signaling in the cicada *Okanagana rimosa*. J. Insect Sci. 2.2.

Webb, J.C., Sivinski, J., Litzkow, C. 1984. Acoustical behavior and sexual success in the Caribbean fruit Fly, *Anastrepha suspensa* (Loew) (Diptera: Tephritidae). Environ. Entomol. 13: 650-656.