Flight Performance and Signaling Sound of Irradiated or Unirradiated *Anastrepha suspensa*[1] [2]

J. L. SHARP AND J. C. WEBB

INSECT ATTRACTANTS, BEHAVIOR, AND BASIC BIOLOGY RESEARCH LABORATORY, SCIENCE AND EDUCATION ADMIN., USDA, GAINSVILLE, FL 32604

When the flight ability of several tephritids was tested in the laboratory with flight mills (Sharp et al. 1975b; Boller et al 1975), the flight performance of a particular species proved to be variable and affected by age, sex, body size, and weight. Performance also was either reduced or enhanced by exposure of the pupae or adults to gamma irradiation. For example, treated females might fly faster and more often than untreated females when they are 1-5 days old and fly slower when they are older; however, the flight ability of treated males was usually not significantly altered unless they were exposed to 2-5X the dose required to produce 100% male sterility. Gamma irradiation affects *Anastrepha suspensa* (Loew), and it could be important to any program involving sterilization and release of this species. We therefore examined the duration, velocity, and distance of flight and the wingbeat frequency of irradiated and unirradiated specimens. Also, we examined the waveform characteristics of the signaling sound of unirradiated and irradiated *A. suspensa* males since Webb et al. (1976) had identified the sound and Greany et al. (1977) reported that the waveform of this sound was affected by the diet fed to the larvae.

PROCEDURES AND RESULTS

A. suspensa pupae for determining effects of irradiation on wingbeat frequency were reared from bagasse diet at the Subtropical Experiment Station, Homestead, Fl. Pupae for the other studies (except those from guava or rose apple that were collected in the field) were obtained from the colony maintained at the Insect Attractants, Behavior, and Basic Biology Research Laboratory. All pupae that were treated were irradiated 2 days before eclosion in normal air with 60 Co at doses of 2.5, 5, 10 or 20 kiloröentgen (kR) at ca. 1000 h EDT (dose rate of ca. 1 kR/min); unirradiated pupae were used as the controls. Before the flight tests, adults were given yeast hydrolysate, sugar, and water and kept in 2.8-dm cubical cages in an environmental chamber at 26°-27°C, 60-65% RH, 4300 lux of light intensity, and a 13L:11D photoperiod. While the flies were being tested, they received no food or water. They were discarded after the tests. Statistical comparisons were made by using Student's *t*-test, analysis of variance or Duncan's multiple range test. Differences were significant if $P \geq 0.05$.

[1]Diptera: Tephritidae.

[2]Mention of a commercial or proprietary product in this paper does not constitute an endorsement of that product by the USDA.

Flight Mill Tests. Irradiated or unirradiated flies reared from bagasse were aspirated from the cages and immobilized briefly (by exposure to a temperature of ca. 7°C) so they could be harnessed. Data were collected from flies that flew > 5% of the 3h test periods.

Table 1 shows the effect of irradiation on the flight ability of *A. suspensa* of 2 ages. Irradiation of pupae with 10 kR improved the distance flown by 1-day-old females (not shown) and the flight duration of 10-day-old females; it reduced the velocity of 10-day-old males. Table 2 presents data for flight by unirradiated males and females of several ages.

Also, we compared the flight ability of unirradiated *A. suspensa* males and females that emerged in the laboratory from pupae from guava or rose apple with that of males and females from pupae reared in the laboratory from corncob or bagasse diets; Table 3 presents the flight data. Females reared from host fruit or from the corncob diet tended to spend more time flying and to fly greater distances than females reared from bagasse or males from any larval diet except rose apple.

Stroboscopic Studies. These studies were made with unirradiated or irradiated males and females of different ages by the method of Sharp (1972). The results (Table 4) indicate minor differences. Thus, irradiation of pupae did not seriously affect wingbeat frequency.

Similar studies were made to determine the effect of temperature (21.1°, 26.7°, and 32.2°C) and RH (60-80%) on the wingbeat frequency of unirradiated males and females. The frequency between the 9-day-old males and females was statistically similar when the RH was 60% and the temperature was increased from 21.1° to 32.2°C. Likewise, the wingbeat frequency of males was statistically similar when the temperature was 26.7°C and the RH was increased from 60 to 80%. However, the wingbeat frequency of females maintained at 26.7°C was statistically higher at 80% RH (164±3) and lower at 60% RH (151±3).

Sound Studies. The precopulatory behavior of sexually mature male *A. suspensa* includes a rapid fanning of the wings (Nation 1972) that produces the sound (Webb et al. 1976) identified as signaling (the activity may disperse the pheromones emitted by the males).

We found that the waveform of the signal sound (analogue data) produced by unirradiated males had 2 distinct parts, arbitrarily designated 1 and 2 in Fig. 1A. The signal from males treated as pupae with 10 kR did not show these parts (Fig. 1B). We therefore analyzed the frequency of the signal sound of untreated males and of males treated as pupae with 5 and 10 kR: Fig. 1C shows the results. The signal sound from unirradiated flies of from flies irradiated as pupae with 5 kR showed 2 fundamental frequencies (1 and 2) corresponding to parts 1 and 2 in Fig. 1A; the sound signal from males treated as pupae with 10 kR showed 1 fundamental frequency. Thus, the levels of gamma irradiation (0-10 kR) produced a corresponding change in pulse.

The number of times that unirradiated and irradiated males signaled also was compared: during 60 sec, unirradiated males signaled ca. 90-95% of the time; males treated as pupae with 5 kR, signaled 15-20% of the time; and males treated as pupae with 10 kR, signaled 0-3% of the time.

TABLE 1. *Effect of 10 kR of gamma irradiation on flight mill performance of* A. suspensa *during 3-h tests.*[a]

Treatment[b]	No. and (%) flying > 5% of test time	*Flight categories* ($\bar{X}\pm SE$) Flight duration (% time flying)	Flight velocity (m/min)
	1-day-old flies		
U ♂	23(66)	29±4 a	20±1 a
U ♀	34(83)	36±5 ab	30±1 ab
I ♂	33(83)	36±4 ab	33±1 ab
I ♀	40(91)	47±4 b	33±1 b
	10-day-old flies		
U ♂	26(96)	51±5 a	44±2 a
U ♀	43(94)	53±4 a	44±1 a
I ♂	24(89)	46±6 a	39±2 b
I ♀	40(93)	66±5 b	40±1 ab

[a] For each age, means in the same column followed by different letters indicate differences at the 5% level by Duncan's multiple range test.

[b] U = unirradiated, I = irradiated. No significant differences were recorded for unirradiated and irradiated flies 5 days old.

TABLE 2. *Effect of age and sex on flight mill performance of unirradiated* A. suspensa *during 3-h tests.*[a]

Age in days and (no.) flying >5% of test time		*Flight categories* ($\bar{X}\pm SE$) *Flight velocity (m/min)* ♂	♀	Flight duration *(% of time flying)* ♂	♀
1 - 2	(67)	30±1 a	31±1 a	27±2 a	32±2 a
3 - 4	(65)	37±1 b	38±1 b	45±3 bc	59±3 c
5 - 6	(53)	41±1 c	39±1 b	49±4 cd	53±3 bc
6 - 8	(92)	43±1 c	44±1 c	54±2 d	55±3 bc
8 - 10	(60)	43±1 c	45±1 c	43±3 bc	35±3 a
10 - 12	(114)	43±1 c	45±1 c	47±2 c	47±3 b
12 - 14	(56)	42±1 c	42±1 c	38±3 b	59±3 c
14 - 16	(103)	41±1 c	42±1 c	39±2 b	55±3 c

[a] Means in the same column followed by different letters indicate significant differences at the 5% level by Duncan's multiple range test.

TABLE 3. *Flight mill performance of sexually mature* A. suspensa *males and females reared from 2 host fruits or from 2 synthetic diets and allowed to fly for 3 h.*[a]

Sex	Flight categories ($\bar{X}$±SE) Flight duration (% Time flying)	Velocity (m/min)	Distance (m)	No. flying 5% of the test
			Rose apple	
♂	62±5*	32±2*	4473±980*	10[b]
♀	79±5*	45±3*	6746±613*	10
			Guava	
♂	50±4*	44±1	4215±347*	45
♀	76±3*	45±1	6362±320*	45
			Bagasse diet	
♂	48±3	45±1	3881±305	57
♀	50±4	44±1	3978±337	50
			Corncob diet	
♂	43±3*	40±1	3174±275*	41
♀	62±7*	46±2	5304±614*	22

[a] *denotes significant differences between sexes reared on same host at the 5% level of probability by Student's *t*-test.

[b] small sample size is a result of low recovery of pupae from the fruit.

Weight Determinations. The weight of adult flies from larvae reared on the corncob or bagasse diets was determined because weight is important to the flight mill performance of some fruit flies (Remund and Boller 1975). The diets produced no significant differences in the mean weight or flight mill performance of 5-, 10-, or 15-day-old males or females. However, 10-day-old females tended to fly faster, more often, and farther if they were reared as larvae on corncob diet.

The mean weight of pupae from bagasse (sex not determined) at 2 days before adult eclosion was 10 mg. The 1-day-old males weighed 8 mg; the 7-, to 15-day-old males weighed 12 mg; and the 16-day-old or older males weighed 10 mg. The 1-day-old females weighed 10 mg, and the 5-, to 22-day-old females weighed 15 mg. Thus, females were significantly heavier than males from day 1 to 22 postemergence although the flight mill performances of the sexes were statistically similar at most ages.

DISCUSSION

We do not know why irradiation of pupae 2 days before adult eclosion with 10 kR caused 1-, and 10-day-old *A. suspensa* females to spend more time flying or fly farther than unirradiated females of the same ages. In fact, Burditt et al. (1975) showed that irradiation of pupae in air increased the mortality of *A. suspensa* adults. However, the phenomenon of enhanced

TABLE 4. *Effects of age, sex, and dose of gamma irradiation on wingbeat frequencies of* A. suspensa.[a,b]

Age (days)	*Wingbeat frequencies (Hz) at indicated exposure (kR)* 0	2.5	5	10	20
			Males		
1	108 a	110 a	114 a	114 a	109 a
4	143 b	145 bc	137 b	136 b	125 b*
7	141 b	142 bc	143 bc*	141 bc*	132 b
10	143 b	147 bc	144 bc	143 bcd	144 c
13	148 b*	150 c	151 d	148 cd	146 c
16	147 b	141 b	143 bc	144 cd	147 c
19	161 c	142 b	147 cd	146 cd	137 bc
22	147 b	147 bc	146 cd	140 bc	146 c
25	157 c	149 bc	149 cd	140 d	131 b
			Females		
1	110 a	115 a	117 a	110 a	111 a
4	140 b	143 c	142 c	139 c	134 b*
7	144 bd	142 c	148 c*	147 bd*	140 c
10	145 bd	151 bd	143 c	146 bd	-
13	158 e*	152 d	155 bd	152 d	-
16	146 bd	144 bc	144 c	143 bc	-
19	156 c	152 d	149 bc	149 bd	-
22	151 cd	143 c	148 c	149 bd	-
25	149 cd	153 d	157 d	159 e	-

[a] Means in the same column followed by the same letter are not significantly different at the 5% level by analysis of variance and Duncan's multiple range test.

[b] *denotes a significant difference at the 5% level between males and females of equal age by Student's *t*-test. - indicates that no data could be collected because of excessive mortality.

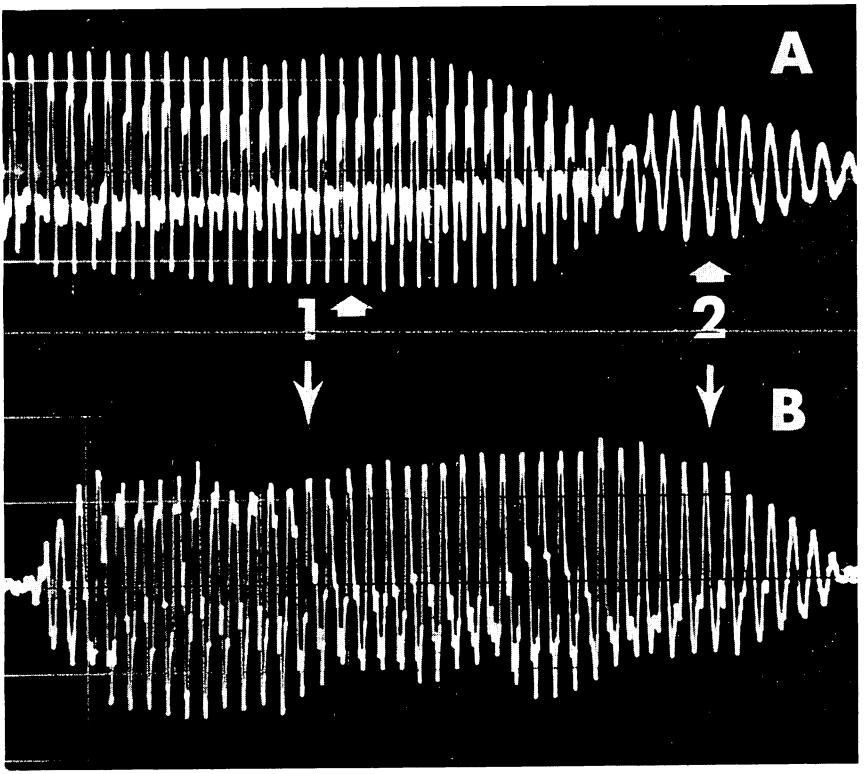

FIG. 1. Effect of irradiation on the signaling sound of *A. suspensa* males: A, signal sound of unirradiated males; B, signal sound of males irradiated as pupae with 10 kR.

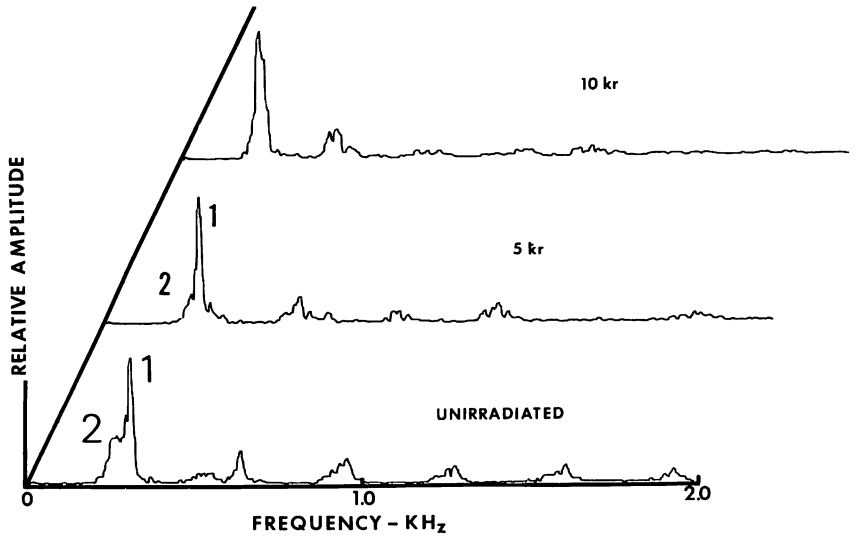

FIG. 2. Frequency analysis of the signal sound for irradiated and unirradiated males.

flight after irradiation has been previously reported (Sharp and Chambers 1976 for *Dacus dorsalis* Hendel) and (Shepard et al. 1972 for *Musca domestica* L.).

Unirradiated *A. suspensa* males and females 8-10 days old did not fly as far and rested more often than younger adults although a study of their metabolism did not show any absence of lipids, sugars, or glycogen in either sex (Sharp and Vick, unpublished data)[3]. This reduced ability of flies with age may result partly from the growth and development of sex glands or associated tissues and organs in the flies. Nation (1974) noted that the salivary glands of *A. suspensa* (found only in males) and the plural glands (they do not enlarge in females as in males) reach maximum size in males 8-9 days after emergence. Also, eggs develop in *A. suspensa* females when they are ca. 9 days old, and the female usually begins ovipositing then (Sharp et al. 1975a).

Irradiation of pupae of *A. suspensa* with 2.5-10 kR at 2 days before adult eclosion reduced the wingbeat frequency of females more often than it reduced that of males (we were unable to obtain wingbeat frequency data for females more than 7 days old that had been irradiated as pupae with 20 kR because > 95% had died). Therefore, from the improved flight ability, the tendency to reduced wingbeat frequency at several ages, and the increased mortality that occurred when pupae were irradiated with 20 kR, *A. suspensa* females were more sensitive to irradiation than males.

The wingbeat frequency of *A. suspensa* varied significantly more often because of age (1-25 days) than because of sex or irradiation (doses as high as 20 kR). Indeed, all 1-day-old males and females had lower wingbeat frequencies than older males and females. When these flies are freshly emerged, they are weak, have soft cuticle, and lack significant energy reserves for sustained flight since none is carried over from the pupal stage. Subsequently, they undergo postemergence maturation, and during this period, flight ability, wingbeat frequency, and body size and weight increase rapidly for ca. 5-7 days. Therefore, weight gains to ca. 8 days are associated with improved flight mill performance and increased wingbeat frequencies in *A. suspensa* as in *Rhagoletis cerasi* L. (Remund and Boller 1975).

The analyses of the waveforms of the signaling sounds of *A. suspensa* males show that irradiation of pupae 2 days before adult eclosion produces a change in the sounds. The treatment alters the physical characteristics of the sound and reduces the frequency of the behavior from 90-95% to ca. 3%. Such effects should be noted in sterile insect release programs.

Summary

Irradiation of pupae of *Anastrepha suspensa* (Loew) 2 days before eclosion with 10 kiloröentgen (kR) resulted in 1-day-old females that flew farther than similar females from unirradiated pupae. However, this treatment severely affected the waveform characteristics of the male signaling sound and might disrupt communication between sterilized flies and native flies. The physical characteristics of the sound were altered and

[3]J. L. Sharp and K. W. Vick. Flight metabolism of *A. suspensa* (unpublished data).

the frequency of the behavior was reduced from 95 to ca. 3%. Irradiation of pupae with 20 kR resulted in males and females with a slightly reduced wingbeat frequency, and 95% of the females died before they were 7 days old. Such effects should be noted in sterile insect release programs.

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