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DISPERSAL AND LONGEVITY OF WILD AND MASS-REARED *ANASTREPHA LUDENS* AND *ANASTREPHA OBLIQUA* (DIPTERA: TEPHRITIDAE)

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ABSTRACT

The rates of dispersal and survival of sterile mass-reared laboratory flies and sterile wild flies of *Anastrepha ludens* (Loew) and *Anastrepha obliqua* (Macquart) were estimated and compared with a regular rectangular array of 64 food-baited traps spaced 60 m between traps around the release point in Tapachula Chiapas, Mexico. The traps were scored every day during the first week, and then every 3 d over a 30-d period. For *A. obliqua*, the number of males recaptured was higher than that of females, while for *A. ludens*, females were recaptured more frequently than males. The recapture rate for the wild strains ranged from 0.6-24.8% for *A. ludens* and 1.3-16.2% for *A. obliqua* and the corresponding ranges for the mass-reared strains were 0.5-7.1% and 0.5-3.0% respectively. The life expectancy was 4.7 d for wild and 4.3 d for mass-reared *A. obliqua* males but 3 and 2 d, respectively, for wild and mass-reared *A. ludens* males. The net displacement of *A. ludens* and *A. obliqua* ranged approximately from 100-250 m and took place mostly on the first day. Wild *A. ludens* moved to the northwest from the release point while the mass-reared strain moved to the west. The *A. obliqua* wild flies moved to the west, while the mass-reared strain shifted to the southwest. We discuss the implications of our findings as to the spacing and frequency of sterile fly releases for the suppression of wild populations.

Key Words: fruit fly, *Anastrepha ludens*, *Anastrepha obliqua*, trapping, life expectancy, sterile insect technique, dispersal, longevity

RESUMEN

La dispersión y longevidad de las moscas estériles silvestres y de cría masiva de *Anastrepha ludens* (Loew) y *A. obliqua* (Macquart) fueron determinadas y comparadas utilizando un arreglo rectangular de 64 trampas espaciadas a 60 metros entre trampas alrededor del punto de liberación en Tapachula Chiapas, México. Las trampas fueron revisadas y evaluadas diariamente durante la primera semana y después cada tres días hasta completar 30 días. Para *A. obliqua* la cantidad de machos capturados fue mayor que la cantidad de hembras; mientras que para *A. ludens* las hembras fueron capturadas con mayor frecuencia que los machos. La recaptura de moscas silvestres de *A. ludens* fue de 0.6 a 24.8%, para *A. obliqua* fue del 1.3 al 16.2%, para moscas de laboratorio fue de 0.5 a 7.1 y 0.5 a 3%, respectivamente. La esperanza de vida correspondió a 4.7 y 4.3 días para machos silvestres y de laboratorio de *A. obliqua* respectivamente; mientras que 3 y 2 días fueron para los machos silvestres y de laboratorio de *A. ludens*. La dispersión para *A. ludens* y *A. obliqua* fue de 100 a 250 m tanto para individuos silvestres como de laboratorio. Los adultos de *A. ludens* silvestre se desplazaron del punto central de liberación al noroeste, los individuos de laboratorio se movieron hacia el oeste del plano Cartesiano. A su vez los adultos de *A. obliqua* silvestre se movieron hacia el oeste y las de laboratorio hacia el suroeste. Discutimos las implicaciones de nuestros resultados con relación al espaciamiento y frecuencia de las liberaciones de moscas estériles para la supresión de poblaciones silvestres.

Translation provided by the authors.

The *Anastrepha* (Schiner) genus (Diptera: Tephritidae) is deemed to be one of the most significant pests of commercially grown fruit from the southern United States to northern Argentina (Aluja 1994; Aluja et al. 1996). *Anastrepha ludens* (Loew) is the major pest of citrus fruits in Mexico, Belize, Guatemala, and the lower Rio Grande valley of Texas (Aluja et al. 1996; Thomas & Loera-Gallardo 1998). *Anastrepha obliqua* (Macquart) is the main fruit fly species to attack mango in commercial orchards situated at lower altitudes, while *A. ludens* infests orchards located at higher altitudes (Aluja et al. 1996). The sterile insect technique (SIT), as part of an area-wide integrated management approach, has been continuously deployed in northern Mexico since 1994 against *A. ludens*, and since 2001 against *A. obliqua*.

Maximum effectiveness in the application of the SIT requires a detailed knowledge of the various ecological parameters that can predict the

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population dynamics of the target populations. It is intuitively obvious that the dispersal of an insect species at its reproductive stage has a considerable effect on the dynamics of the local population (Royama 1979). This highlights the importance of measuring the fitness of the released insects in relation to the wild population, and the need to determine the ways in which possible differences could affect the success of the control program (Fletcher & Economopoulos 1976). The international fruit fly quality control manual (FAO/IAEA/USDA 2003) defines the estimation of the ability of released sterile insects to survive in the field and to move from the point of release to feed and mate as the main objective of release-recapture tests of dispersal and survival.

The field quality of sterile flies has 2 main components, mating competitiveness and survival rate. Sterile insects must survive under natural conditions at the target site until they are sexually mature and achieve copulation with fertile wild females in order to be effective as agents of control. The basic questions are how long do the flies live after they are released, and how far do they disperse? Such information is necessary for determining the frequency with which releases should be made and the distance between release points (Thomas & Loera-Gallardo 1998).

Recapture studies have been the traditional method by which the dispersal and longevity information is obtained. Shaw et al. (1967) used a design to measure long-distance dispersal and reported some recaptures at 5-8 km from the release point. Baker et al. (1986) and Baker & Chan (1991) calculated orientation ellipses to visualize the dispersal of mass-reared populations of *Ceratitis capitata* (Wiedemann) and *A. ludens*. They concluded that in all cases the mean fly position moved significantly away from the release point indicating a drifting of the released population. Most movements were towards the north and east, the direction of prevailing daily winds. Thomas & Loera-Gallardo (1998) used a regression model and estimated the average dispersal distance to be 240 m for sterile mass-reared *A. ludens* and found that life expectancy after release ranged from 5 to 10 d.

The purpose of this work is to compare the dispersal rates and longevities of sterile mass-reared flies and wild flies of 2 species, *A. ludens* and *A. obliqua*. We present data from fly releases performed over 4 years of research in commercial mango orchards and discuss the implications of our findings as to the spacing and frequency of sterile fly releases for the suppression of wild populations.

MATERIALS AND METHODS

Release and Recapture of Wild and Mass-reared Irradiated Flies

The flies were released in commercial mango orchards (*Mangifera indica* L. v. Ataulfo) in Tapachula, Chiapas, Mexico. The mango trees were 20 years old and 15 m high with spacing of 15 m between them. The sterile flies used in this study were obtained from the Moscafrut mass-rearing facility in Metapa, Mexico, which is the same source of flies used for the suppression programs in Mexico. Mass-reared colonies of *A. ludens* and *A. obliqua* were maintained on corncob larval diet (Artiaga-López et al. 2004; Stevens 1991). Wild *A. obliqua* flies were obtained from an intensive collection in Comitán, Chiapas (16°15'13"N, 92°07'35"W) of infested fruits of *Spondias mombin* L., and wild *A. ludens* flies from infested fruits of *Citrus aurantium* L. collected in Tapachula, Chiapas (14°54'10"N, 92°15'32"W). Fruits were placed in plastic containers and stored for 4 d to allow most of the larvae to reach physiological maturity. Later, fruits were dissected to obtain larvae, which were placed in a container along with moist vermiculite in order for them to pupate under indoor conditions of 26 ± 1°C and 75 ± 5% R.H.

The mass-reared flies were sterilized by exposing the late pupal stage, 48 h before adult emergence, to 80 Gy from a ^{60}Co source. The irradiated pupae were held in 4-L paper bags until complete adult emergence. Adults were provided sugar and water and held in the bags for 5 d at which time they were released. In all replicates, the number of flies per release was about 6,000 (3,000 per sex). The pupae were marked with fluorescent dyes of different colors to discriminate between the wild flies from the laboratory flies, and also to distinguish among different release dates. Both *A. ludens* and *A. obliqua* were released shortly after sunrise at the center of the orchard. For each species, 9 releases were performed during the years 1999 to 2004. The "Jasso" mango orchard, 30 m above sea level and located within 20 km from Tapachula at km 4 of the Jaritas-Cd. Hidalgo road, was chosen as the release site.

For fly capture, 64 McPhail traps were baited with a mixture of 10 mL of protein hydrolysate (Captor 300), 5 g of borax, and 240 mL of water and deployed in a regular rectangular 8 × 8 array with 60 m spacing between the traps. The traps were placed 4 m above ground in a mango tree, and were installed the day after fly release. To estimate longevity, the traps were scored every day. The fluorescent color dye in marked flies was distinguished with a Leica MMZ FLIII fluorescence microscope. The recaptured flies were separated by origin (mass-reared or wild), sex, trap, and released date for each species.

The analysis of recapture rates was done after arc-sine transformation of the square-root of the proportions recaptured (Underwood 2005). The transformed data were given by the formula

$$Y = \sin^{-1}\sqrt{(Y/100)}$$

where *Y* values are the percentage of captured flies.

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Longevity of Wild and Mass-reared Irradiated Flies

The longevity was estimated with fly captures as a function of time after the release (Carey 1989). To form the first (age) column of a life table, the release day was considered as age zero, while the subsequent d were considered as specific age (x). The number of flies captured on a given day (Y_x) over successive d formed the next column and the following items formed subsequent ones and were calculated as follows. The accumulated number of flies captured from a given day was found by

$$n_{x+1} = n_x - Y_x$$

Survival rate up to a given day was found by

$$l_x = n_x / n_0$$

so that

$$\sum_{x=0}^{n} l_x = 1$$

The age specific death rate (proportion of flies that died on a given day) was found by

$$q_x = l_x - l_{x+1}$$

and the survival rate from release to halfway through a given day was estimated as

$$L_x = \lfloor l_x - (q_x/2) \rfloor$$

Finally, whereas the mean life expectation at the day of release could be estimated as

$$e_0 = \sum_{x=0}^{n} L_x$$

the expectations at other ages were calculated in two stages (columns) as shown in Tables 3 and 4. Mean values were compared by one-way analysis of variance, while the daily survival population curves and life expectancy curves were compared by a survival analysis and Log-Rank test between groups by JMP Statistical Discovery Software (SAS Institute 2003). The survival curves were fitted to the natural logarithm model with the number of individuals trapped expressed in logarithmic scale and time in arithmetical scale.

Dispersal of Wild and Mass-reared Irradiated Flies

Mean dispersal distance d, was estimated by relating the number of flies captured in each trap, the distances between traps, and the release point according to the following formula:

$$\bar{d} = \sum_{i=1}^{n} x_i C_i / \sum_{i=1}^{n} C_i$$

where C_i is the number of flies captured in trap i, and x_i is the distance between trap i and the release point (FAO/IAEA/USDA 2003). The dispersal area was modeled by contour plot analysis with JMP Statistical Discovery Software (SAS Institute 2003), in which the distance (m) was the average displacement from the release site towards any point, without considering the direction. The magnitude (m) was the average displacement in the Cartesian plane, considering the direction. The direction angle (°) was the direction of the displacement in the Cartesian plane. The r vector consisted in the adjustment of the displacements to a "swarm" type movement. The occupied area (%) was determined from the area occupied by the traps that captured flies.

Results

Recapture of Wild and Mass-reared Irradiated *A. ludens*

The number of flies captured on each date according to origin and sex are presented in Table 1. The mean capture percentage (± SE) was 7.62 ± 2.81% for wild flies and 2.88 ± 0.88% for laboratory flies, but there was a high variation among replicates and the means were not significantly different (F = 2.80; df = 1,16; P = 0.1134). The first (May 17, 1999) and fifth (July 1, 2001) releases resulted in the highest recapture rates for both wild and mass-reared flies (Table 1). The mean percentage of recaptured males was 50.90 ± 1.50% and 45.13 ± 3.65% laboratory and wild flies, respectively, was non-significant (F = 2.14; df = 1,16; P = 0.1627). Fig. 1 shows the number of flies recaptured per release cohort (identified by release date). The points were fitted to exponential regression and we observed that for *A. ludens* the laboratory line was above the wild line.

Recapture of Wild and Mass-reared Irradiated *A. obliqua*

The percentage of recaptured males was 55.26 ± 2.10% and 52.75 ± 2.72% for wild and laboratory flies, respectively (but the difference between the two types of male was not significant; F = 0.53; df = 1,16; P = 0.475). For the releases performed on June 06, 1999, July 12, 2001, August 17, 2001, and September 06, 2001, more than 2.0% of the released flies that were recaptured were of laboratory origin; while on June 06, 1999, July 12, 2000, and September 06, 2001, the percentage was over 8% for wild flies (Table 1). The mean re-

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TABLE 1. TOTAL RECAPTURE OF *ANASTREPHA LUDENS* AND *A. OBLIQUA* IN MANGO ORCHARD "JASSO" AFTER RELEASES IN THE CENTER OF THE SAMPLING AREA.

Release date	Total recapture		Percent male recapture		Percent recapture	
	W	L	W	L	W	L
Anastrepha ludens						
17/05/99	814	560	42.63	45.89	24.83	7.08
27/05/00	90	76	31.11	50.00	3.17	3.23
30/05/01	112	258	31.25	46.90	2.21	2.72
22/06/01	53	41	39.62	58.54	2.95	1.89
01/07/01	167	830	63.47	55.78	18.70	7.43
05/06/04	72	298	50.00	51.35	2.69	0.45
13/06/04	45	625	44.45	45.76	0.58	1.05
13/06/04	115	1006	58.26	54.18	5.17	1.30
08/06/04	141	153	45.39	49.68	8.30	0.76
Average ± SE			45.13 ± 3.65 a	50.90 ± 1.50 a	7.62 ± 2.81 a	2.88 ± 0.88 a
Anastrepha obliqua						
06/06/99	675	386	43.11	43.75	16.23	2.33
12/07/99	423	321	56.50	55.14	3.55	1.21
17/08/99	51	41	62.75	56.10	1.33	0.47
12/07/00	207	94	58.45	49.79	9.08	1.84
12/07/01	146	154	60.27	57.79	6.40	3.02
10/08/01	116	68	58.62	66.18	5.09	1.33
17/08/01	114	108	52.63	57.41	5.00	2.12
06/09/01	196	126	57.14	50.00	8.60	2.47
08/06/04	186	245	47.85	39.19	5.02	1.27
Average ± SE			55.26 ± 2.10 a	52.75 ± 2.72 a	6.70 ± 1.43 a	1.78 ± 0.26 b

W = Wild strain, L = Laboratory strain. Values for the same species in a row with the same letter do not differ significantly (ANOVA on arcsine transformed percentages, $\alpha = 0.05$). The values are expressed by average ± SE.

capture rates of laboratory and wild flies were significantly different ($F = 16.23$; $df = 1,16$; $P = 0.001$). Fig. 1 shows the number of flies captured per release date and the fit for exponential regression; the lines for wild flies are consistently lighter than those for laboratory flies.

Longevity of Wild and Mass-reared *Anastrepha ludens*

Longevity, expressed as the life expectancy value within the trap array (Table 2) indicates that the life expectancy (e_0) after release for *A. ludens* was 3.1 d for the wild strain and 2.2 d for the laboratory strain. Both wild and laboratory flies showed similar values ($F = 1.25$; $df = 1,16$; $P = 0.2783$). Moreover, there were no significant differences between wild and laboratory females ($F = 0.65$, $df = 1,16$; $P = 0.4291$) or between wild and laboratory males ($F = 0.91$, $df = 1,16$; $P = 0.3538$). Table 3 shows the calculation of the life expectancy of the laboratory males of *A. ludens* within the trap array; the values are based on the sum of males captured during the first 15 d of trapping following each of the 9 release dates. The life expectancy of each release cohort is given in Fig. 4; wild *A. ludens* had high values in 2000 and 2004, whereas the laboratory flies tended to be more constant.

Daily survival rate on the trapping array (l_x) in Fig. 2 show that less that 50% of the flies were alive after about the first 3 d. The survival curves in all cases fit curves based on natural logarithmic models. The models were ln (nx) wild female = 4.5932 – 0.2332 (age) ($F = 508.02$; $df = 1,21$; $P < 0.0001$); ln (nx) wild males = 3.6097 – 0.2020 (age) ($F = 92.32$; $df = 1,21$; $P < 0.0001$); ln (nx) laboratory female = 4.9383 – 0.2665 (age) ($F = 183.28$; $df = 1,21$; $P < 0.0001$); ln (nx) laboratory males = 4.2647 – 0.2436 (age) ($F = 64.12$; $df = 1,21$; $P < 0.0001$).

Longevity of Wild and Mass-reared *A. obliqua*

The life expectancy (e_0) after release for *A. obliqua* was estimated at 4.3 d for the wild strain and 4.2 d for the laboratory strain, and there was no significant difference between them ($F = 0.16$; $df = 1,16$; $P = 0.6932$). The mean life expectancy was not significantly different for wild and laboratory females ($F = 0.017$; $df = 1,16$; $P = 0.6793$), or males ($F = 0.11$; $df = 1,16$; $P = 0.7376$) (Table 2). Table 4 shows the life expectancy values based on the males captured during the first 15 d following each of the 9 release dates. The life expectancy pertinent to each release cohort appears in

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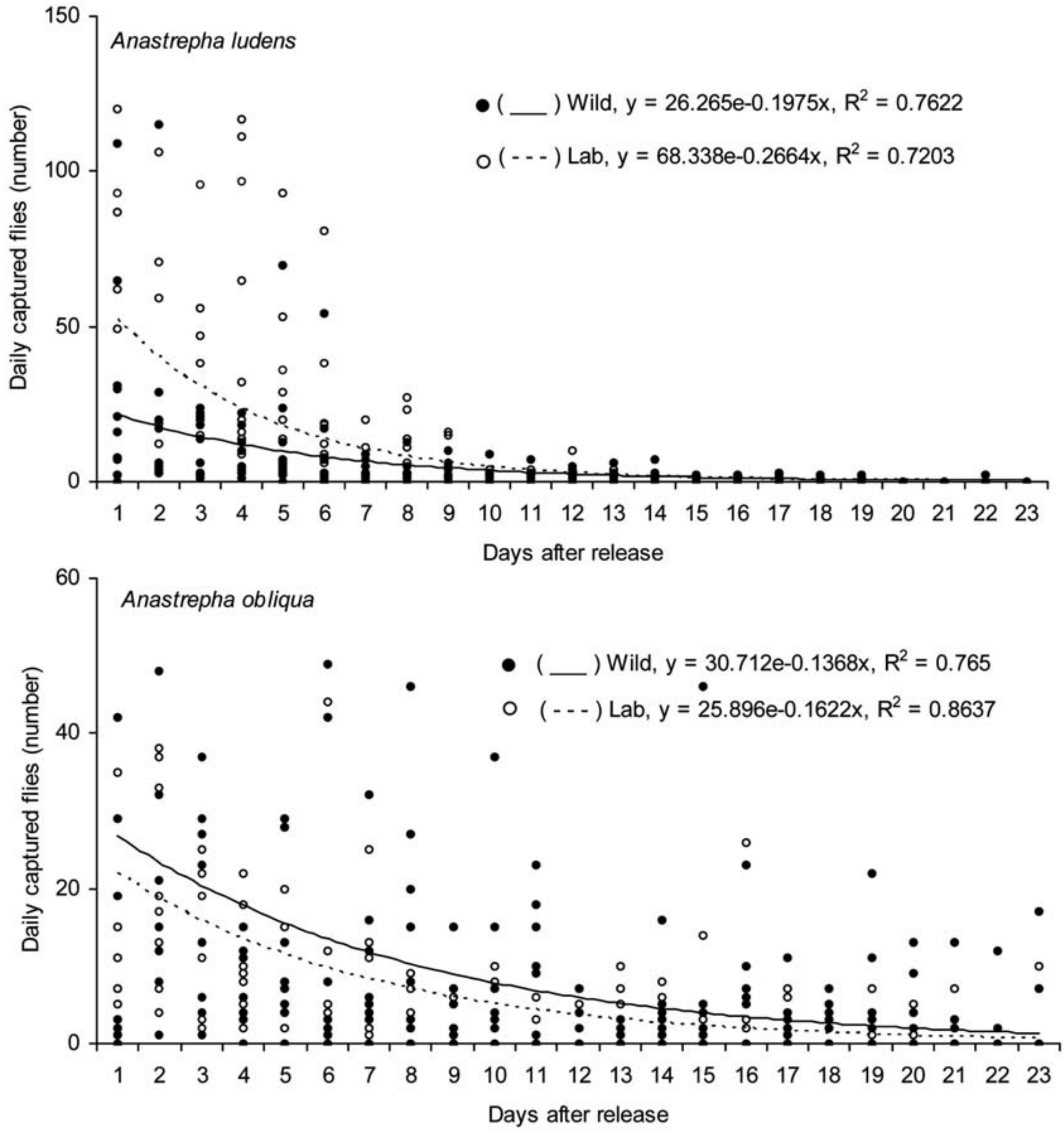

Fig. 1. Daily captured flies of *Anastrepha ludens* and *A. obliqua*.

Fig. 4; life expectancy at release fell to less than 2 d during the months of Jul and Aug 1999, but much higher values were achieved by later release cohorts.

Wild and laboratory flies were captured over 20 d (Fig. 1), but less than 50% of the flies were alive after about 4-5 d (Fig. 3). Equations corresponding to the curves shown in Fig. 3 were ln (nx) wild female = 4.9870 – 0.1733 age (F = 399.12; df = 1,21; $P < 0.0001$). ln (n_x) wild males = 4.9425 – 0.1710 (age) (F = 477.32; df = 1,21; $P < 0.0001$); ln (nx) laboratory female = 4.5568 – 0.1852 (age) (F = 1720.81; df = 1,21; $P < 0.0001$); ln (nx) laboratory males = 4.6642 – 0.2004 (age) (F = 561.69; df = 1,21; $P < 0.0001$).

Dispersal of Wild and Mass-reared *A. ludens*

Dispersal parameters are presented in Table 5. In all cases, wild flies did not differ from laboratory flies (ANOVA, $P < 0.05$). *Anastrepha ludens* males and females could have dispersed over

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TABLE 2. LIFE EXPECTANCY (e_0) FOR *ANASTREPHA LUDENS* AND *A. OBLIQUA* IN MANGO ORCHARD "JASSO" AFTER THE RELEASES.

	Anastrepha ludens		*Anastrepha obliqua*	
	Wild (d)	Laboratory (d)	Wild (d)	Laboratory (d)
Female	3.34 ± 0.56 a	2.39 ± 0.21 a	4.45 ± 0.76 a	4.17 ± 0.71 a
Male	2.99 ± 0.43 a	2.03 ± 0.26 a	4.65 ± 0.88 a	4.25 ± 0.69 a
Total	3.12 ± 0.47 a	2.20 ± 0.21 a	4.35 ± 0.82 a	4.17 ± 0.63 a

The values are expressed by average ± SE. The mean life expectancy was estimated on flies captured during 20 (*A. ludens*) and 23 (*A. obliqua*) d of trapping following each of the 9 release dates. Values for the same species and sex in a row with the same letter do not differ significantly (ANOVA, α = 0.05).

150 m during the first 15 d after release (Fig. 5). Fig. 6 shows how the movements are mostly close to the release point. There was no statistical difference between laboratory and wild strains.

Dispersal of Wild and Mass-reared *A. obliqua*

Dispersal parameters are presented in Table 5. In all cases, wild flies did not differ from laboratory flies (ANOVA, $P < 0.05$). The mean distance moved away from the release point indicates that the total displacement was almost 139 m for both wild and laboratory strains. *A. obliqua* males and females dispersed over 200 m during the first 13 d after release (Fig. 4). The *A. obliqua* laboratory strain has a displacement similar to that of *A. ludens* (Fig. 6). However, for the wild strain, the displacement was very irregular (i.e., displacement not concentric) with more area occupied by the flies as a whole.

DISCUSSION

In all cases, the life expectancy values obtained for the flies released during this investigation were lower than the 9.85 d obtained by Thomas & Loera-Gallardo (1998) in the arid subtropics for mass-reared and sterilized *A. ludens* and the 17.3 d mentioned by Celedonio-Hurtado et al. (1988) within the laboratory. The shorter life span obtained in this study may have been due to different biotic and also abiotic conditions in the tropics, in particular the rainy weather and higher relative humidity. Also, there may have been spray drift from the chemical control in neighboring commercial mango orchards at times

TABLE 3. LIFE EXPECTANCY CALCULATIONS FOR LABORATORY MALES OF *ANASTREPHA LUDENS*.

x Capture day	Y_x Captured flies	n_x $n_{x+1} = n_x - Y_x$	l_x $l_x = n_x/n_0$	q_x $q_x = l_x - l_{x+1}$	L_x $L_x = l_x-(q_x/2)$	Tx $T_x = \Sigma L_x + L_{(x+1)} + \ldots L_n$	e_x $e_x = T_x/l_x$
0	1577	3542	1.00	0.45	0.78	1.98	1.98
1	601	1965	0.55	0.17	0.47	1.20	2.17
2	617	1364	0.39	0.17	0.30	0.73	1.91
3	250	747	0.21	0.07	0.18	0.44	2.07
4	211	497	0.14	0.06	0.11	0.26	1.86
5	114	286	0.08	0.03	0.06	0.15	1.86
6	79	172	0.05	0.02	0.04	0.09	1.77
7	28	93	0.03	0.01	0.02	0.05	1.84
8	38	65	0.02	0.01	0.01	0.03	1.42
9	16	27	0.01	0.00	0.01	0.01	1.72
10	4	11	0.00	0.00	0.00	0.01	2.50
11	1	7	0.00	0.00	0.00	0.01	2.64
12	2	6	0.00	0.00	0.00	0.00	2.00
13	1	4	0.00	0.00	0.00	0.00	1.75
14	1	3	0.00	0.00	0.00	0.00	1.17
15	2	2	0.00	0.00	0.00	0.00	0.00
n_0 =	3542		Life expectancy = ΣL_x =		1.98 d		

The averages are based on the sum of males captured during the first 15 d of trapping following each of the 9 release dates.

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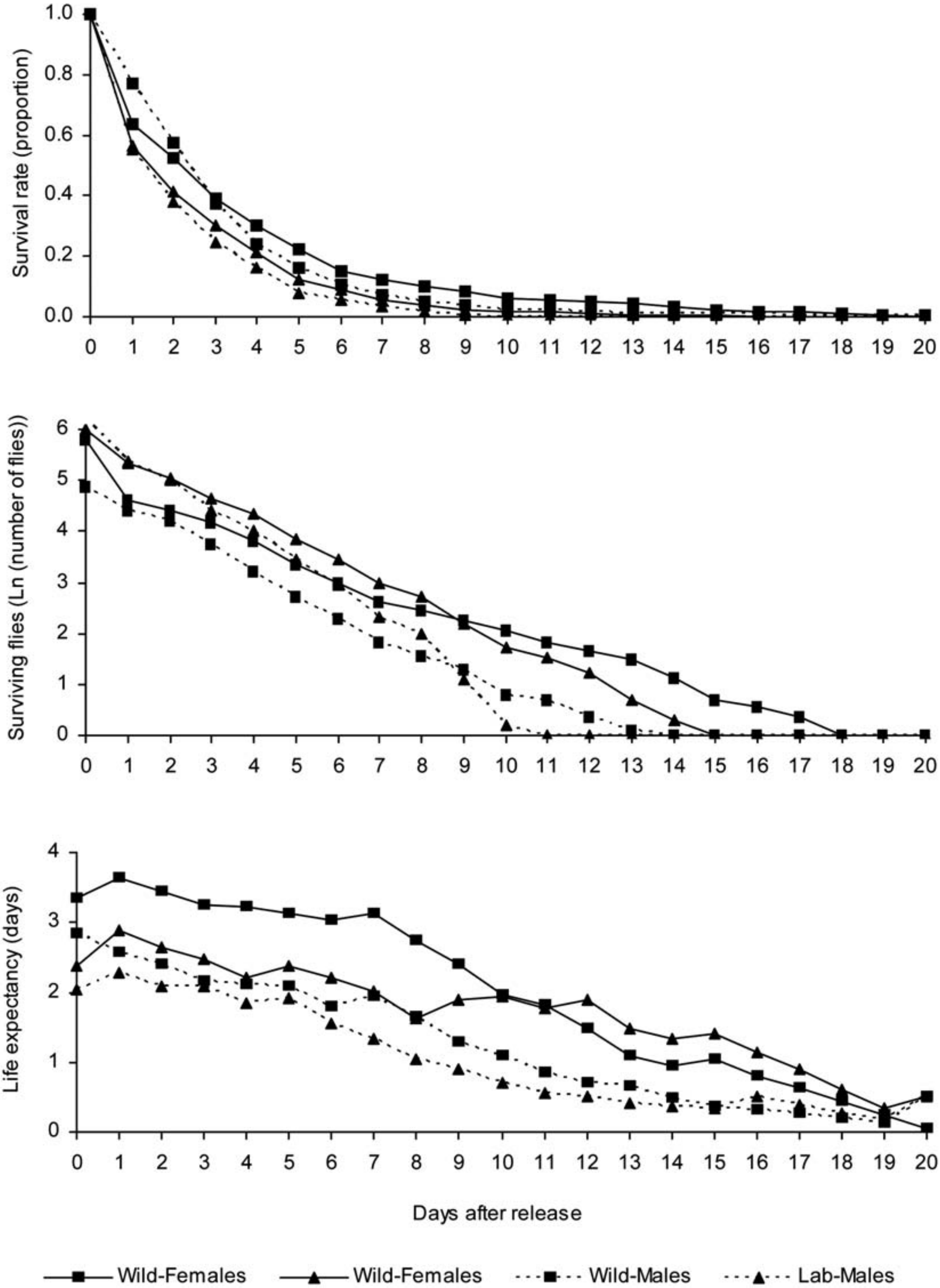

Fig. 2. *Anastrepha ludens*. Survival proportion (lx)(Female, Log-Rank, $\chi^2 = 0.5478$, $df = 1$, $P = 0.4578$; Male, Log-Rank, $\chi^2 = 0.2727$, $df = 1$, $P = 0.6015$). Lives flies (ln nx) (Female, Log-Rank, $\chi^2 = 1.5345$, $df = 1$, $P = 0.2154$; Male, Log-Rank, $\chi^2 = 0.0061$, $df = 1$, $P = 0.9379$). Life expectancy (ex))(Female, Log-Rank, $\chi^2 = 13.9547$, $df = 1$, $P = 0.0002$; Male, Log-Rank, $\chi^2 = 53.7651$, $df = 1$, $P = 0.0 < 0.0001$). The values were estimated from recapture rates with McPhail glass traps.

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TABLE 4. LIFE EXPECTANCY CALCULATIONS FOR LABORATORY MALES OF *ANASTREPHA OBLIQUA*.

x Capture day	Y_x Captured flies	n_x $n_{x+1} = n_x - Y_x$	l_x $l_x = n_x/n_0$	q_x $q_x = l_x - l_{x+1}$	L_x $L_x = l_x-(q_x/2)$	Tx $T_x = \Sigma L_x + L_{(x+1)} + \ldots L_n$	e_x $e_x = T_x/l_x$
0	106	825	1.00	0.13	0.94	4.03	4.03
1	234	719	0.87	0.28	0.73	3.09	3.55
2	90	485	0.59	0.11	0.53	2.36	4.02
3	93	395	0.48	0.11	0.42	1.83	3.83
4	80	302	0.37	0.10	0.32	1.41	3.85
5	49	222	0.27	0.06	0.24	1.09	4.06
6	31	173	0.21	0.04	0.19	0.85	4.07
7	22	142	0.17	0.03	0.16	0.66	3.85
8	28	120	0.15	0.03	0.13	0.50	3.46
9	20	92	0.11	0.02	0.10	0.37	3.36
10	19	72	0.09	0.02	0.08	0.27	3.15
11	3	53	0.06	0.00	0.06	0.20	3.10
12	8	50	0.06	0.01	0.06	0.14	2.26
13	10	42	0.05	0.01	0.04	0.08	1.60
14	18	32	0.04	0.02	0.03	0.04	0.94
15	14	14	0.02	0.02	0.01	0.03	1.77
n_0 =	825		Life expectancy = ΣL_x =		4.03 d		

The averages are based on the sum of males captured during the first 15 d of trapping following each of the 9 release dates.

of peak fruit production. Celedonio-Hurtado et al. (1995) and Aluja et al. (1996) were unable to find a correlation between weather and trap capture in the same release site (Tapachula, Chiapas, México), but they were recording natural populations and did not obtain data on fly survival.

The survival curves for *A. ludens* and *A. obliqua* correspond in both cases to the "diagonal type" in the classification proposed by Hutchinson (1981), where the n_x curve descends in a straight line when it is plotted on a logarithmic scale, and time on an arithmetical scale. This type of curve indicates that throughout a fly's life, the probability of death is fairly constant.

Anastrepha obliqua had a higher average displacement than *A. ludens*. In both species, during the first day, displacement distance was about 100 m while, for the rest of the time, further displacement was low and variable. *Anastrepha ludens* and *A. obliqua* showed the same tendency observed by Thomas & Loera-Gallardo (1998) for *A. ludens* releases along the Santa Rosa Canyon in the State of Nuevo León, Mexico, where recapture numbers were not a function of the distance

TABLE 5. DISPERSAL AND ORIENTATION OF *ANASTREPHA LUDENS* AND *A. OBLIQUA* IN A MANGO ORCHARD.

	Anastrepha ludens		*Anastrepha obliqua*	
Parameter	W	L	W	L
Distance (m)	111.58 ± 4.26 a	110.85 ± 0.98 a	151.73 ± 6.17 a	139.18 ± 9.26 a
Magnitude (m)	47.12 ± 3.52 a	46.88 ± 2.70 a	66.23 ± 7.25 a	51.44 ± 6.24 a
Direction angle (°)	164.33 ± 15.01 a	184.17 ± 15.24 a	176.79 ± 51.93 a	282.29 ± 40.57 a
R vector	0.40 ± 0.03 a	0.32 ± 0.01 a	0.22 ± 0.06 a	0.24 ± 0.06 a
Occupied area (%)	48.61 ± 2.51 a	62.50 ± 2.74 a	69.53 ± 12.44 a	61.72 ± 10.85 a

W= Wild strain, L= Laboratory strain. The values are expressed by average ± S.E. Values in the columns for the same specie with the same letter are not different (ANOVA, $\alpha = 0.05$).

Distance.—Average displacement from the release site towards any point, without considering the direction.

Magnitude.—Average displacement in the Cartesian plane, considering the direction.

Direction angle.—Direction of the displacement in the Cartesian plane.

R vector.—Adjustment of the displacements to a "swarm" type movement.

Occupied area.—Area occupied determined from the traps that captured flies.

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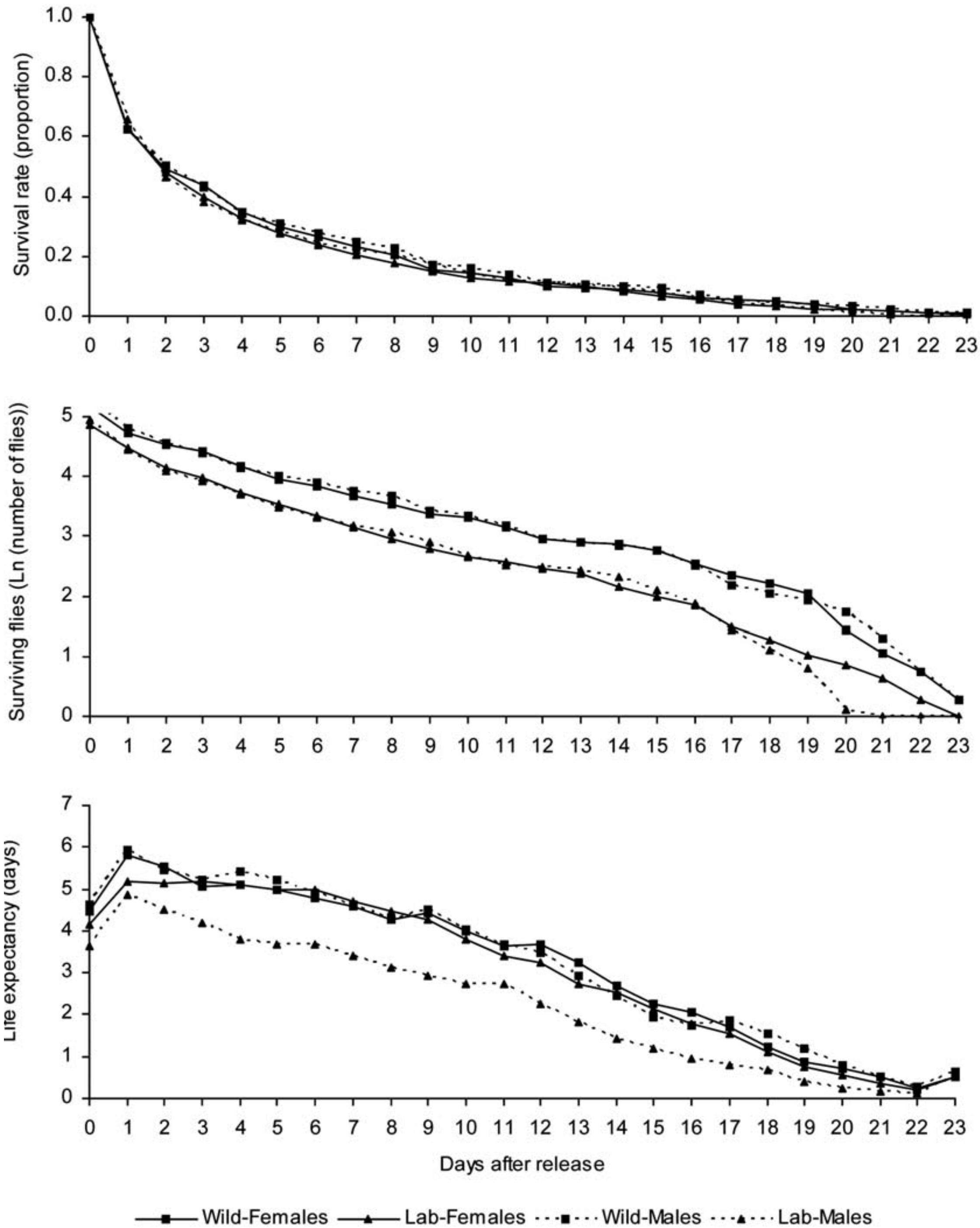

Fig. 3. *Anastrepha obliqua*. Proportion surviving on trap array by date (lx); number of trappable live flies on array (ln n_x); life expectancy on trap array (e_x). The values were estimated from recapture rates with McPhail glass traps.

and the dispersion was not a process of simple diffusion. Displacement in the Cartesian plane for both species did not include the northern and southwestern quadrants. Thomas & Loera-Gallardo (1998) observed dispersal distances of 9 km from the release point, and also reported persis-

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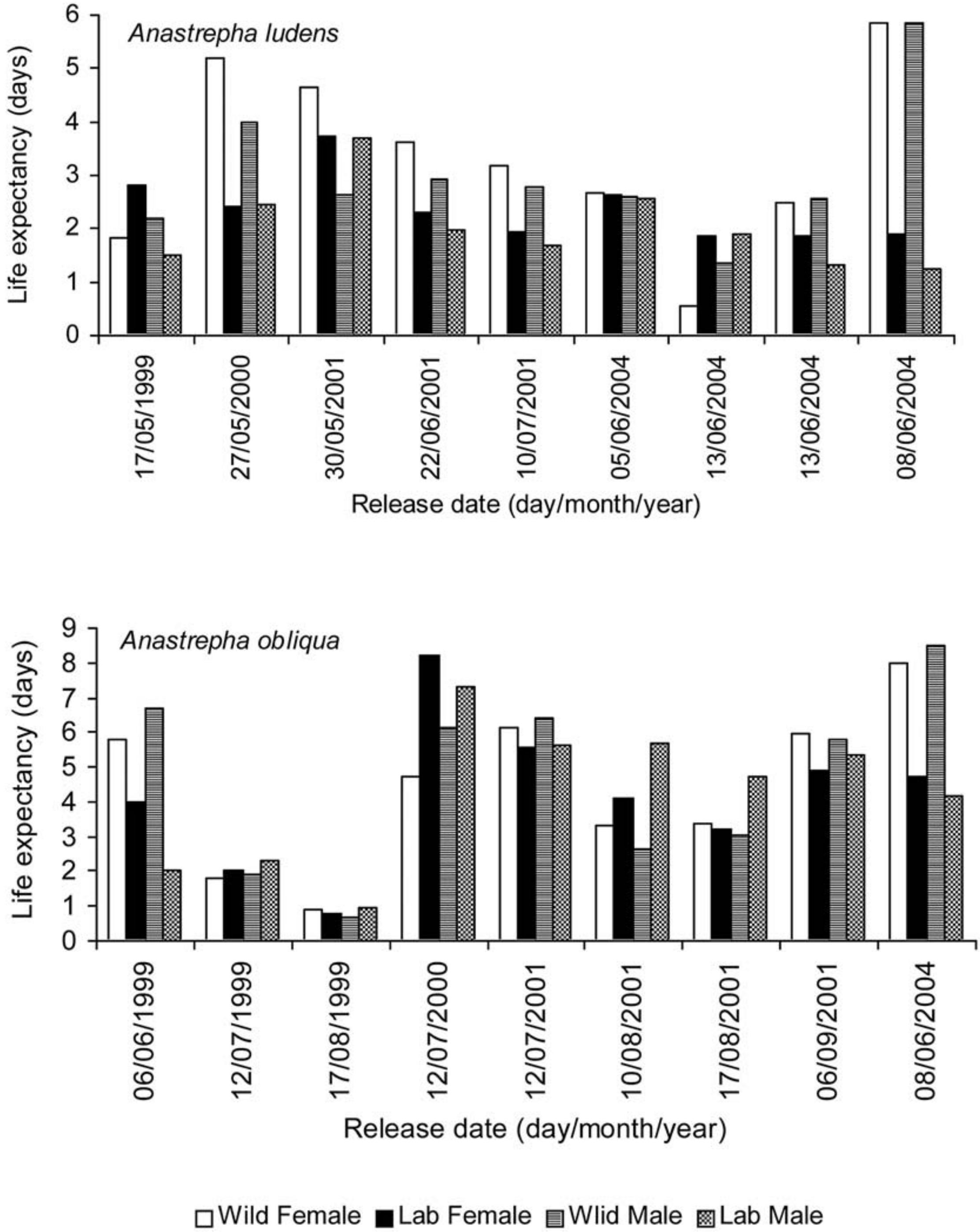

Fig. 4. Life expectancy on trapping array (e_0) by release date; *Anastrepha ludens* (upper) and *A. obliqua* (lower).

tence of the sterile flies up to 78 d. The reason for such a difference in the present results remains to be established.

The life expectancy values obtained for mass-reared, male *Anastrepha ludens* and *A. obliqua* indicate that suppression or eradication pro-

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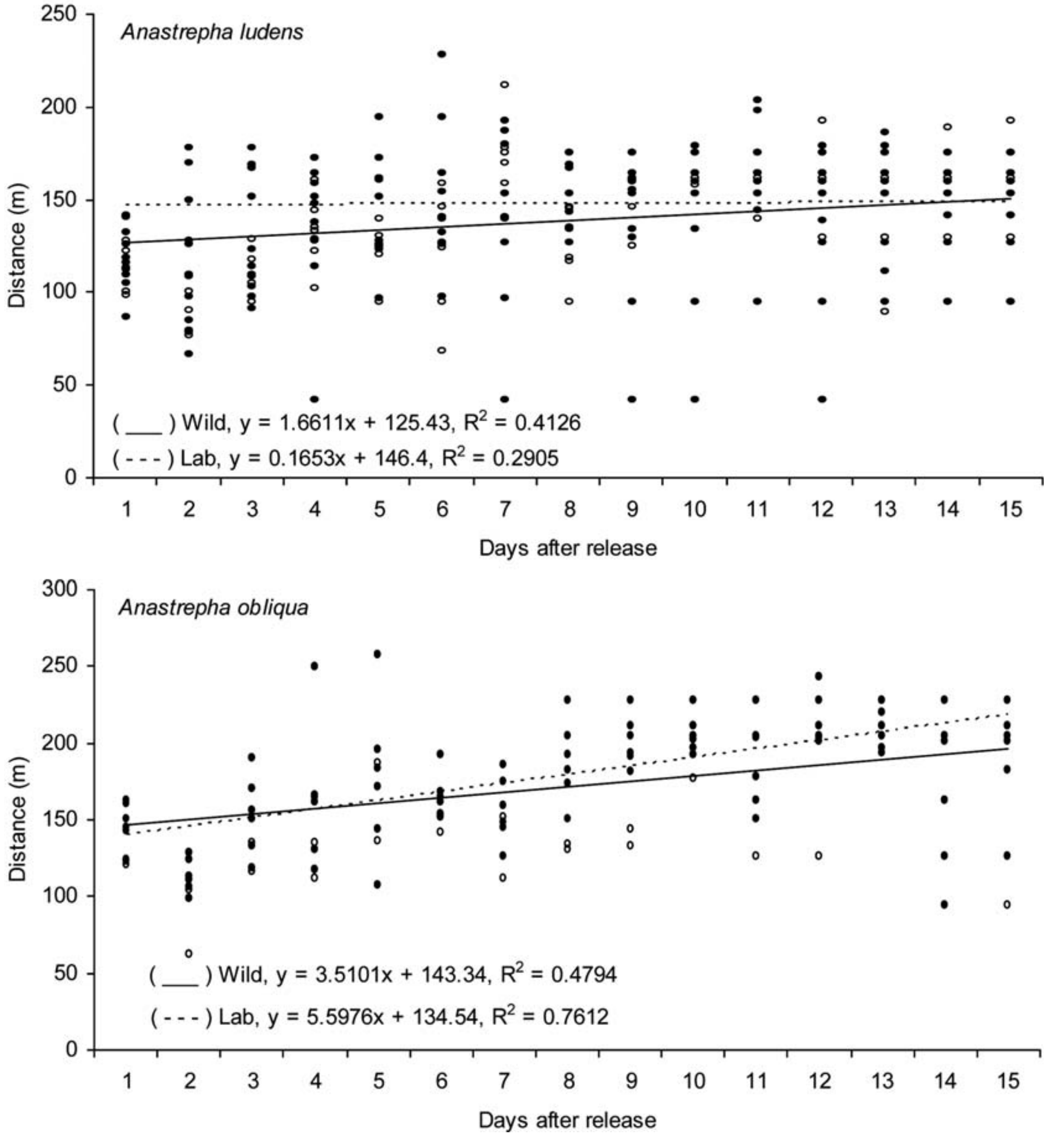

Fig. 5. Daily displacement of *Anastrepha ludens* and *A. obliqua* as distance from release point (meters).

grams should consider 2 releases per week for *A. ludens* and once per week for *A. obliqua*. The mean distance of displacement was about 100 m, indicating that in order to optimize the dispersal of sterile flies, release lines should be spaced not more than 200 m. In view of the low life expectancy of mass-reared *Anastrepha* spp. flies after release (3 to 4 d), and since they reach sexual maturity only around 10 d of age (Orozco et al. 2001), operational programs could consider holding sterile flies longer before release, or treating them with juvenile hormones to accelerate maturation (Teal et al. 2007), to avoid that a majority of released sterile males do not survive before being able to inseminate wild females.

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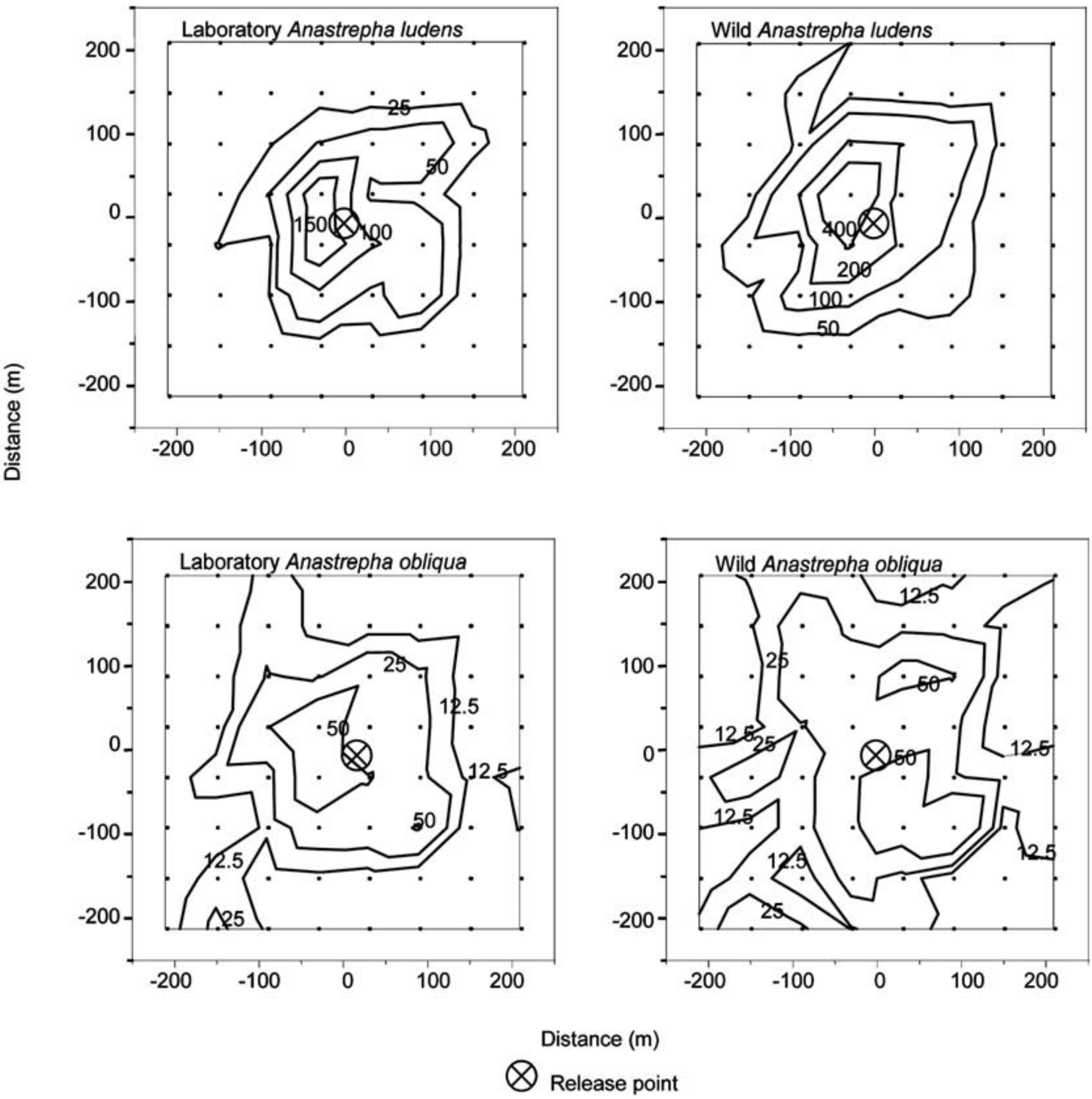

Fig. 6. Dispersion of laboratory and wild *Anastrepha ludens* and *A. obliqua* determined by contour plot analysis from JMP. Number in each line indicates the number of flies captured inside the area.

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